Traffic integration or segregation for the sustainable city
- A review of current debate and literature
Foreword

Sweden’s growth and employment is dependent upon attractive and competitive city regions. That is one of the reasons why “The Attractive City” project is undertaken. The project is a joint undertaking between the National Rail Administration, the National Board of Housing and the Swedish Road Administration in co-operation with the Municipalities of Jönköping, Norrköping and Uppsala and the Swedish Association of Local Authorities and Regions.

In the project the focus is on laying the foundation for development, attitudes and regulatory systems that facilitates interaction between the private and public sectors, between the individual and the common cause, between different sectors and interest groups as well as between the national, regional and municipal perspectives.

This report contains the result of a literature study and is one of the basic reports which are to be discussed during the project. It is as well used in the course of developing new planning advice for the design of roads and traffic systems in urban areas in Sweden.

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The authors are responsible for the conclusions in the report. The Swedish Road Administration has not formed an opinion of the conclusions.

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Summary

This is a literature study of the principles of urban transport network design. The purpose is to discuss the competing concepts of:

- Traffic integration and filtering of car traffic, with the traditional, mixed use urban street as the main object of interest, versus
- Differentiation and segregation of different types of traffic, with the hierarchical road system as the main system solution.

We look at the international and Scandinavian professional debate about these two major concepts. We try to distil the most important arguments of the debate, and to look into available theoretical and empirical evidence of the merits of the different principles and the various design solutions that have been proposed for the traffic system.

We find that much of the debate is rather meaningless, since the proponents of different principles have not defined the objectives they are aiming at for the city.

As the starting point of our analysis of the principles of urban transport network design, we state that we are looking for solutions that will contribute to the development of a sustainable city and transport system. This means that car traffic volumes and speeds should be significantly reduced in comparison with existing cities and towns.

We use an earlier study by the author to define the more detailed environmental criteria against which the different solutions and network design principles may be evaluated against.

Then we review the literature on the effects of different design principles and traffic parameters, in order to find the types of solutions that are most in line with the objectives of the sustainable and environment friendly city.

Two traffic parameters are judged to be the most important; car traffic speed and the volume of car traffic, both in single streets and districts, and as a total for the urban region. We review the evidence about the importance of traffic speed and volume reductions, and about the means that can be applied to reach the desired results.

One of the conclusions is that there is a clear need for a combination of the principles of traffic integration and segregation, and that the use of only one of these principles for the design of the urban transport network would be counter-productive in relation to the objectives of the sustainable city.

The study concludes with a set of recommendations for the development of the sustainable city. The recommendations should be seen as qualified hypotheses about how the traffic system of urban areas – in particular the design of the road network – should be developed in order to contribute significantly to the future sustainability of cities. We do not pretend to have the final answers, but believe that we have some good points for further discussion and more thorough analysis and empirical testing.
The concluding recommendations for the development and design of the sustainable city with an environment friendly transport network are, in the shortest possible version:

1. Define your goals
2. Create an urban land use and transport policy package to achieve the required traffic volumes and environmental qualities
3. Make use of information technology to control traffic volume, speed and character
4. Create a transit-oriented network designed to support sustainability and urban life
5. Segregate heavy and fast car traffic from urban life
6. Create a two-tier car network: Highways and traffic calmed urban roads and streets
7. Distinguish clearly between town and highway
8. Design urban roads for low speeds
9. Create an urban street network that improves the competitive advantages of environment friendly modes
10. Give suburban and industrial areas more urban elements
11. Define environmental areas
12. Have a place and high quality transit oriented strategy for the old urban arterial streets
13. Create continuous routes if not in conflict with urban environment objectives
14. Use selective filtering of motorized traffic
15. Create a parking policy that improves the environmental areas and support environment friendly transport
16. Create more and bigger car-free zones
17. Upgrade significantly the role of park & ride and bike & ride

We have two suggestions for further work.

Test the recommendations and document best practice
Create a popular summary report.
The challenge and the historical context

1.1 The purpose of the study

Within the urban transport and land use planning professions a debate has taken place for many years about the principles of road system design and urban form. This has also been the case in Sweden and the other Scandinavian countries as part of the continuing development of national design guides and advice for the urban road system and street design.

Discussion of paradigms – with focus on traffic integration

Simplified, this debate might be described as a “competition” between two main paradigms of urban transport system design:

- Traffic integration and filtering of car traffic, with the traditional, mixed use urban street as the main object of interest, versus
- Differentiation and segregation of different types of traffic, with the hierarchical road system as the main system solution.

This paper reports the results from a study of literature which attempts to distil the most important arguments of the debate, and to look into available theoretical and empirical evidence of the merits of the different principles. The main questions to be addressed are:

- How can the principles of traffic integration and filtering of car traffic contribute to the development of more sustainable urban communities?
- Under which circumstances and conditions should these principles be incorporated into new advice on the planning and design of the road traffic and transport systems of cities and other urban areas?

The principles of differentiation and segregation serve as a reference for our analysis of traffic integration. We summarize the understanding of the different roles that highways and streets play in the urban environment. In particular, we discuss the current international trend among many planners who advocate the increasing use of integration and mixed-use streets, as opposed to separation of modes and transport users.

Naturally, in any medium sized or large city, there will always be the need for some differentiation of roads and streets. The city will need highways with high capacity and a single purpose of serving large volumes of through traffic. At the same time, there is a need for local streets that aim primarily to serve as an urban place for people, and their activities.

However, as the city grows, traffic volumes increases and land becomes increasingly sparse, many streets now have combined functions, serving both the transportation needs of through users, and the urban dweller’s need for a place to visit, spend time and do errands.

It is a challenge to create a new system that reaps the benefits of both separation and integration, and to identify which indicators gives adequate guidance as to when and how the two systems operate best.
Environmental capacity and traffic calming

Ideally, it should be possible to define which streets can take larger volumes of traffic, without causing too much trouble for the inhabitants, the environment and the many businesses in the neighbourhood. The term environmental capacity was brought into the discussion by the Buchanan report to the British Government in the 1960’s (Ministry of Transport 1963). Since then, the term has often been used to determine how much car traffic a street can take in relation to the requirements of the urban environment and other users of the street. The problem is how to define this term and how to get good indicators to measure the success of different planning schemes.

Traffic, of course, is a moving object, not only at the instant, but also as seen in the longer perspective. Our city plans, the location of our houses and work places and our travelling and leisure habits, determine which traffic flows are important and more or less constant, and which ones are more changeable through local and small scale planning schemes.

Traffic calming has traditionally been implemented on the local street level. However, the current debate raises questions of whether strategic traffic calming schemes should be developed to a larger degree, as an alternative to the conventional differentiation of highway system design and the segregation of modes in network design and traffic management.

To put our study into a historical context, we will make a short presentation of the origins of this, still modern, debate.

1.2 The traditional street and road network

The classic urban street with integrated, mixed traffic is the traditional solution for cities, towns and villages. It combines the different functions of through traffic, access to buildings and other properties, and a wide range of street activities in the same stretch of public open space between buildings.

The versatility of streets and networks

The street has proven its viability as a key element in all urban settlements in history. A major reason for this is the flexibility of the concept in different urban contexts and landscape settings, and the adaptability of street formats and designs to traffic and access functions of many kinds.

The versatility of the concept of the street may be illustrated by the large number of street types and street classifications that have been used in the urban planning literature, as registered by Stephen Marshall (2005). He identified a large number of street typologies, which he grouped into four different categories of classification theme: by street form, by street use, by relation, or by designation, figure 1. We will come back to Marshall’s analysis later in this paper.
Table 3.3  A taxonomy of road types, classification themes and theme types

<table>
<thead>
<tr>
<th>Set of road types</th>
<th>Classification theme</th>
<th>Type of theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square, circus, crescent, cross</td>
<td>Shape of space</td>
<td>Form</td>
</tr>
<tr>
<td>Dual 3-lane, dual 2-lane, single carriageway</td>
<td>Carriageway standard</td>
<td></td>
</tr>
<tr>
<td>Limited access road, distributor, access road</td>
<td>Access control</td>
<td></td>
</tr>
<tr>
<td>Street, terrace, mews, court</td>
<td>Built form/frontages</td>
<td></td>
</tr>
<tr>
<td>Narrow street, wide street</td>
<td>Width</td>
<td></td>
</tr>
<tr>
<td>Civic, commercial, residential, industrial</td>
<td>Urban building type</td>
<td></td>
</tr>
<tr>
<td>Shopping street, living street, etc.</td>
<td>Urban uses and users</td>
<td></td>
</tr>
<tr>
<td>High volume road, low volume road</td>
<td>Traffic volume</td>
<td></td>
</tr>
<tr>
<td>Long distance traffic road, local traffic road</td>
<td>Trip length (origin and destination)</td>
<td></td>
</tr>
<tr>
<td>Road type used by any mode</td>
<td>Transport modes</td>
<td></td>
</tr>
<tr>
<td>High speed road, low speed road, etc.</td>
<td>Traffic speed (observed)</td>
<td></td>
</tr>
<tr>
<td>Route used by tourist traffic, works traffic, etc.</td>
<td>Road users</td>
<td></td>
</tr>
<tr>
<td>Spine road, connector street, cul-de-sac</td>
<td>Structural role</td>
<td></td>
</tr>
<tr>
<td>Strategic route, link road, local route, etc.</td>
<td>Strategic role</td>
<td></td>
</tr>
<tr>
<td>National road, regional road, municipal road</td>
<td>Ownership/management</td>
<td></td>
</tr>
<tr>
<td>Special road, principal road, A road</td>
<td>Statutory designation</td>
<td></td>
</tr>
<tr>
<td>70 mph, 60 mph, . . . , 20 mph road</td>
<td>Speed limit (designated)</td>
<td></td>
</tr>
<tr>
<td>Bus only; pedestrian only, etc.</td>
<td>Vehicle or user permission</td>
<td></td>
</tr>
<tr>
<td>'Avenue', 'Street', 'Lane', 'Mansions', etc.</td>
<td>Nominal</td>
<td></td>
</tr>
<tr>
<td>Designated route for tourists, works traffic, etc.</td>
<td>Designated route</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. Four categories of street classification theme and a taxonomy of road types. The types are defined by (a) form, (b) use, (c) relation, or (d) designation (Marshall 2005, fig. 3.9 and table 3.3).
The role and character of the street also depends on the type of network pattern which it is a part of. By drawing, at the same scale, a series of square mile extracts of different city street maps Allan B. Jacobs (1995) has clearly illustrated the tremendous variety of street patterns that can be found in both historical and modern cities, figure 2.

In addition to the striking variation in patterns, Jacobs took note of how the street patterns have been influenced by topography and natural features and how the city street and block patterns can give order and structure to a city, district or neighbourhood, either by planned design, or through evolution over time.

The square mile maps permit quantifiable comparisons of some two-dimensional aspects of urban scale, such as the numbers of intersections and blocks in that area and the average distance between intersections.

Figure 2. Comparison of street patterns in selected, one square mile sections of the city maps of some historical and modern cities. This page: Pompeii, Venice, Copenhagen, Vienna. Next page: Paris, Los Angeles, Brasilia and Irvine (USA) (Jacobs 1995).
These data might be used to characterise the street pattern’s potential for street life and attractiveness for pedestrians: In the walking city of Venice, a square mile has over 1500 intersections, while the car-based business area of Irvine, USA only has 15 intersections between public roads and streets in the same area.

For the urban areas he studied, Jacobs also noted a change of scale over time, especially during the last 150 years. Although complexity and fine-grained patterns are not characteristic of all early cities, he observed that the patterns have tended to become less complicated over time, with larger street blocks and fewer intersections in the network. To a considerable extent the most recent jumps in scale may be explained by change in transport technology, most notably the introduction of the automobile and the adaptation of the network to the faster speed of the car. The development of central Boston in USA illustrates this, figure 3.
Streets, urban and non-urban roads

In urban planning it is common to distinguish between streets and roads. Historically, streets are urban, and roads belong to rural areas. In practice, it is not so easy to distinguish between the two categories, and there are lots of intermediate types, especially in villages and small towns, in industrial and institutional areas, and in the transition zones between urban development and rural areas.

The traditional urban street is characterised by a clearly defined relationship between the circulation space and the buildings along the street. The three roles of transportation route, built frontage and public space are combined, and numerous types of circulation and urban place activities share the use of the common, public space between properties.

As the density of urban development goes down, and when the forms and orientations of buildings are independent of the access and circulation routes, the street becomes a road. The road can still have an urban character through the mix of traffic and urban place activities and the use of design elements such as pedestrian pavements, stone kerbs, cobbled pavement, sharp corners, urban types of lighting, street furniture, formal tree planting and other greenery, urban fences and gates, traffic signals etc.

Roads have their characteristic geometry designed mainly for circulation, and are designed according to the transport functions they should perform, the types of traffic, modes and speed of travel. Some are mainly single purpose, such as high speed car traffic on motorways or paths mainly designed for bicycle traffic. Other, and this is the dominant part of the road network, must cater for a mixture of heavy and light car traffic, pedestrians, cyclists and public transport with large variations in travel speed and stopping patterns.
The very rich variation in the character of streets and roads, the diverse forms and contents of surrounding buildings and urban structure, and the numerous different uses of these public realms, makes the analysis and discussion of planning principles and possible solutions very complex.

1.3 The approach of differentiation and segregation

The principles of differentiation and separation can to-day be seen as responses to the urban design challenges raised by the mass production and use of motor cars, which revolutionised transportation in modern societies and created some appalling problems of traffic safety, congestion, traffic noise, pollution and intrusion into the older, existing urban environments. However, problems of through traffic and conflicts between vehicular traffic, pedestrians and residential functions have been with us since the early days of urbanisation.

Old solutions to ancient problems

Some 2000 years ago in Pompeii, the main market square was closed for chariots and horses. Their goods and passengers had to be delivered at seven cul-de-sacs closed by bollard-like stone slabs that surrounded the pedestrianized square.

In Caesar’s Rome heavy wagons where forbidden from dawn to dusk within the continuously built-up area.

In Charles II’s cities and suburbs of the 1660’s parking of external coaches and coach horses were forbidden to relieve city life of the common nuisances of their “rude and disorderly standing, and passing to and fro”, so that the streets and highways were “pestered” and “unpassable, the pavements broken up, and the common passages obstructed and become dangerous, our peace violated, and sundry other mischiefs and evils occasioned” (as declared by the king, according to Ritter 1964).

Three responses to the challenges of the car society in US: Radburn, the Neighborhood unit and the Freeway

The ideas and solutions of the pre-car society were further developed together with the growth in car ownership and the concurrent growth in traffic volumes.

The traffic concepts of the 20th century were also heavily influenced by simultaneous thinking about improving living conditions in the congested and dirty industrial cities through the development of garden cities and the modernistic ideas of efficient, industrial building, a more healthy urban environment and design for hygienic light and fresh air.

Naturally, USA, the first car society, early developed principles of road system design to deal with car traffic in the modern city. There, the explosive growth in car ownership and use coincided in time with very rapid urban growth. So today, most of US urban development has been shaped by these solutions and the strong forces of the car society.

Clarence Stein and Henry Wright designed the development plan for the housing estate of Radburn, New Jersey, which has been considered the prototype “town of the motor age”. The plan introduced the “super-
block” without through traffic inside an area of 120-150,000 sq. m, with cul-de-sac residential service streets for cars at the back of the houses, and pedestrian paths leading from the house fronts through parkland to the local shops etc. The first development in Radburn begun in 1928 (Ritter 1964).

Figure 4. In 1928 the Radburn plan of Clarence Stein and Henry Wright introduced to modern planning practice the principle of the large urban block without through traffic, and the segregation of pedestrians and cars in residential areas (Gallion and Eisner 1963, p.128).

The Radburn plan has been seen as the prototype for urban development based on the principle of segregation between pedestrians and cars. According to the Buchanan report (below), the layout idea originally derived from the English Garden City Movement. It became a model for post World War II New town planning in Britain, in Scandinavia and on the European Continent.

The Radburn plan also incorporates elements from the planning idea of the neighbourhood unit.

According to Gallion and Eisner (1963), the basic idea of the neighbourhood concept was to create ”a physical environment in which a mother knows that her child will have no traffic streets to cross on his way to school, a school which is within easy walking distance from home” (p. 251). The children also have safe play areas inside the neighbourhood, and adults are able to walk to the local centre to obtain their daily household goods. Even some personal services may be reached at the local centre without having to go by car.
At the upper end of the road hierarchy, the urban freeway appeared on the scene during the early 1930’s in New York City (Downtown Expressway) and Chicago. This new type of urban infrastructure had earlier been envisaged by architects and urban planners, such as Tony Garnier in his ideas in 1917 for “La Cité Industrielle”, Le Corbusier’s “La Ville Contemporaine” in 1922 and his “Plan Voisin” for Paris in 1925.

Le Corbusier also developed his concept of “La Ville Radieuse”, and submitted a plan in an international competition in 1933 for new development of Nedre Norrmalm in Stockholm based on these ideas. (Source: Gallion and Eisner 1963).

The urban freeways of US cities taught some lessons about transport policy and urban development that have taken some 50 years to come into the mainstream of urban planning and transport policy. Still views on the benefits and costs of urban motorway projects differ a lot among professionals and between politicians.

This is not the place to review the debate and the scientific evidence on the effects of major roads in urban areas. But there is available a large body of research literature that tell us that adding new road capacity in urban areas to relieve traffic congestion will normally induce more car traffic and change modal split in favour of the car.

Figure 5. The principles of neighbourhood unit as described by (Left) Clarence A. Perry in 1929 and (Right) Clarence Stein in 1943 (Gallion and Eisner 1963).
Immediately after the new roads are opened for traffic, motorists change their route choice. Some old, parallel streets are relived of traffic, and other roads connected to the new road system experience traffic growth. It has also been shown that, in the long term, new roads affect urban development and contribute significantly to urban sprawl. How strong these effects will be, are dependent on such factors as how the older parts of the road and street systems are adjusted, whether public transport is improved or not, what sort of land use planning controls that are put into force, etc.

However, it is interesting to note that already in 1939, Norman Bel Geddes, the designer of the US Interstate highway system, declared that “Motorways must not be allowed to infringe upon the city.” The federal highway planners in fact opposed the idea of bringing urban freeways into city centres, but were out-lobbied by big-city majors who wanted US highway money spent in their cities. The result was the 1956 Federal-Aid Highway Act which included six thousand mile of urban freeways in the Federal road building programme (Duany et al. 2000).

**Environmental areas**

When urban reconstruction and expansion started after World War II., the new demands of the increasing car ownership soon had to be incorporated into mainstream urban land use and transport planning in Europe.
In Britain, the forces of car traffic generation of new urban highways were described by transport economists (Walters 1961, Downs 1962) and road pricing was recommended as the main solution for large cities by the Smeed report to the Government (Ministry of Transport 1964). The Government also studied the potential of introducing small city cars to deal with the obvious space problems of the conventional car in dense city centres (Ministry of Transport 1968).

However, it was the urban and road planning solutions of the Buchanan report that made the biggest impact on the policies towards motorisation of urban areas (Ministry of Transport 1963; commonly referred to by the name of the Working Group’s chairman, Colin Buchanan). This influential report outlined the challenges and possible solutions, and reviewed experiences from other countries.

The report recommended the creation of urban environmental areas without through traffic by cars, and a hierarchical system of distributor roads to serve these areas and to channel through traffic outside sensitive areas.

Figure 7. In order to adjust the use of cars to the urban situation without creating too much disturbance to the urban life and environment, The Buchanan report recommended the creation of environmental areas without through traffic and a hierarchy of distributors for different types of car traffic (Ministry of Transport 1963, p. 44 and 47).
According to the Buchanan report, the volume of car traffic that should be catered for should be decided by environmental considerations, the need to conserve the cultural heritage of the cities, and the amount of infrastructure for roads and car parking that could be afforded. These factors, and the required speed of car travel, should decide the design of the roads and the scale of new road building that should take place.

The consequences of different levels of car accessibility for British cities and towns were illustrated in a series of four case studies. By this, the report illustrated the high costs and the devastating scale of urban renewal that would be needed if “full motorisation” was to be the goal of transport policy in large cities.

**SCAF – for Scandinavian traffic safety**

In the 1950’s and 1960’s the ideas of differentiation and separation were also adapted to the urban scene of Scandinavian towns and villages. This practice could find ideological support in the earlier planning ideas of the Garden City movement and the radical, social modernism that strongly influenced architecture and urban planning in Scandinavia in the first half of the 20th century. Most strikingly, the ideas were formed in concrete and asphalt in the new housing estates and satellite towns of Stockholm, Gothenburg, Oslo, Copenhagen and other medium sized towns in Scandinavia developed to solve the housing and urban renewal challenges of the period 1945 – 1975.

Especially in Sweden and Norway, the principles of traffic differentiation and segregation were pedagogically presented and advocated in the SCAF1-reports dealing with new urban road system development (Statens Planverk 1968) and the renewal of the traffic systems of existing urban areas (Statens Planverk 1971). At that time a main concern of car traffic planning and transport policy was to reduce the number of casualties and serious injuries on the roads, which had grown fast as the number of cars on the roads increased at a very high annual rate, first in Sweden and later in the other Scandinavian countries.

SCAF’s four basic recommendations were (Statens Planverk 1968):

1. To locate urban functions and activities so that traffic volumes and conflicts and disturbances would be minimised.

2. To segregate different types of traffic and modes in time and space, especially with large volumes of traffic, at high speeds and where children are involved.

3. To differentiate within each type of mode network in relation to functions, speed and other basic properties.

4. To simplify the traffic environment to the users, so that they will find it easier to perceive the traffic system and other travellers’ behaviour, to facilitate safe decisions and easy orientation.

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1 SCAF = (Swedish) Stadsbyggnad Chalmers Arbetsgruppen för Trafiksäkerhet. In English: The Working Group for Traffic Safety at the Institute of Town Planning, Chalmers Technical University, Gothenburgh. The group was headed by professor Olof S. Gunnarsson.
Two of these principles, no. 2 and 3 are the topic of this paper, but they cannot be fully understood without also considering the other two principles. The implications of segregation and differentiation for the design of the road system were illustrated by model patterns for the planning of new urban development.

Figure 8. Model design of the SCAFT recommendations for the different types of roads in new urban development (SCAFT 1968, p. 14-16).

Soon these principles were also adapted to the task of improving traffic safety and environment in existing built-up areas. The recommended road hierarchy was then somewhat reduced compared to the recommendations for new development, but the basic principles for existing urban areas were the same (Statens Planverk 1971 and 1974):

- Motorised through traffic should be concentrated on a few roads and streets outside the most traffic sensitive areas.
- This should be achieved through traffic management measures such as street closures, one way regulations, speed limitations and road signing.

- The environmental areas created between the main roads and streets with through traffic should have a street network that discourages through traffic and, as far as possible, segregates car traffic from pedestrians and bicycles.

- There should be rather few junctions between the local streets of the environmental areas and the main roads, in order to reduce the risk of traffic accidents and to improve car traffic flow on the main streets.

The principles were incorporated into national road system design regulations, and many Scandinavian town developments and large housing estate projects were built according to these principles.

Also most elements of the numerous traffic management schemes that have been implemented in older parts of the urban street and road network has been strongly influenced by the SCAF T recommendations.

Figure 9. The recommended road hierarchy based on the principles of segregation and differentiation; according to the Norwegian Road design standard of 1974 (Vegnormalen 1974, according to Vegdirektoratet 1995, p. 92).
Even today the principles of differentiation and segregation are basic elements in Scandinavian urban road and traffic planning guidance. They are now less rigorously incorporated into design guides and road network regulations. More emphasis has been given to urban place qualities and other environmental aspects than traffic safety.

But still the principles of differentiation and segregation are considered valid, and this keeps the professional debate alive.

The factors favouring environment area solutions
For the further discussion in this paper, one should remember the main arguments that are used to support the continued practice of the environmental area in both old and new urban development.

In relation to people and activities inside the environment area, the most important arguments are:

- Traffic safety in general and safe living environments for children in particular.
- The reduction of nuisances from traffic noise and air pollution.
- Improving conditions for walking and cycling.

For the surrounding main streets, the main argument in favour seems to be:

- The removal of turning movements by cars due to the closing of side streets for cars, improves both traffic safety and traffic flow, even when maximum speed is unchanged.

In relation to an overall environment friendly urban transport policy the following points are made:

- The closing of local routes for car driving and the improvement of conditions for walking and cycling induces people to reduce local car use, i.e. cut down on short distance car travel.
- Traffic speeds and volumes on local and main streets can be influenced by the detailed street design elements, so as to adjust these to acceptable levels according to the environment capacity of each route.
- Both traffic safety and noise problems are easier to solve if the main sources of disturbance are not dispersed, but concentrated to corridors where alleviating measures will be cost-effective.
- By concentrating traffic to the least sensitive routes, the need for such measures can be minimized.

The need for knowledge about traffic calming and environment capacity
Looking at these arguments, we see that there are two key elements that planners must have good knowledge of in order to make this network design strategy a success. Planners must know:

- How they can influence traffic speed, route choice and traffic volume on different roads and streets.
- How they may decide on the traffic speed, volume and composition that are acceptable in different types of streets and urban environments.
Therefore, the topics of traffic calming and environment capacity are dealt with later in this paper.

**Tragedies of planning – which tragedy?**

Despite the points mentioned above, critics of conventional planning based on the road hierarchy talk and write about an urban tragedy caused by the use of the principles of differentiation, segregation and the environmental area closed for through traffic. They claim that these principles lead to disurban forms of road networks and building layouts, with unattractive and socially and economically depressing urban environments.

The critics usually advocate the alternative principle which should guide the design of urban transport networks: the principle of traffic integration in an urban street network.

On the other hand, it is also possible to look upon this idea as another tragedy, albeit of a different type. Some people might still agree with the architect planner Paul Ritter who in his broad and internationally oriented book “Planning for Man and Motor” concluded that: “Opposition to the idea of traffic segregation has been continual and largely irrational, as is the case with all original ideas. This has meant the loss of countless lives and limbs and robbed humanity of much pleasure. The tragedy of bad planning is its continuing effect” (Ritter 1964, p. 314).

In this paper we try to find solutions so that both types of the envisaged tragedies may be avoided, and at the same time so that a more sustainable urban development might be supported.

### 1.4 A basis for evaluation

In order to evaluate different principles of traffic system planning and design, one needs:

- Goals that describe what one is aiming to achieve.
- Indicators that describe to what extent the different goals have been reached.
- Understanding of the various factors that affect goal achievement.
- Knowledge of the connections between goal achievement and the traffic design principles and solutions that have been proposed.

**Goals and indicators of success**

With the TRAST handbook and the reports it is based on (Vägverket et al. 2004) as our main source and with due consideration of the major points of discussion in the ongoing professional debate, we consider the following list of main goals to be a useful reference for our analysis:

- Travel and transport needs, both for passenger and goods transport, service delivery etc., which may be supported or suppressed through different network design principles.
- Accessibility for users of different modes of transport and activities, which may be measured in terms of travel time, generalised travel costs, etc.
– Security and comfort for different groups of users, in terms of perceived social environment, fear of harassments and unpleasant and dangerous situations.

– Traffic safety, measured in terms of accidents, fatalities and injuries in relation to the amount of transport or activity taking place (i.e. accident risk).

– Direct environmental effects on people’s health, activities and well being from traffic noise, pollution, vibrations, severance, intrusion etc.

– City character, as analysed and described through urban place analysis, including cultural, historic and aesthetic qualities.

– Environmental effects on nature, including effects on use of energy, effects on climate change, etc.

– Effects on urban liveability and street activities, the use of public open space, etc.

– Effects on the economic viability of local businesses, including trade turnover, market competitiveness, etc.

We leave the further, precise definitions of these goals and indicators to the sources of knowledge we have found in our search for theoretical and empirical evidence of the effects of different transport solutions and network design principles.

However, before we investigate the properties of the traffic and street system that might contribute positively or negatively to these goals, we will analyse the current critique of conventional road planning in some detail.
2 The critique of conventional road planning and modernistic urban design

2.1 Marshall’s analysis of streets and networks

The probably most comprehensive and representative source presently available for our study of the professional critique of conventional road planning and modernistic urban design, is Stephen Marshall’s recent book “Streets and Patterns” (Marshall 2005). In this chapter we will summarize and comment on his critique of “car oriented” road planning, which includes the use of the principles of a differentiated road hierarchy, environmental areas and segregation of different modes of road transport and different types of traffic.

An urban revolution

In his introduction, Marshall quite appropriately calls the introduction of modern car traffic planning and road design in urban planning and development an “urban revolution”. For Britain, he pinpoints the revolution to the already mentioned Buchanan report of “Traffic in towns” (Ministry of Transport 1963).

Marshall illustrates the revolution with Buchanan’s case example of the transformation of the Tottenham Court Road area in inner London that would be necessary to give high level accessibility by car to this area. He claims that the report “envisioned cities of multi-lane motorways and multi-storey car parks, with tower blocks and pedestrian decks set above labyrinthine systems of distributor roads and subterranean service bays” (p. 1).

Marshall refers to Buchanan’s earlier misgivings (in 1958) against this type of transport structure that destroys the existing urban fabric, and which made Buchanan ask the question of whether this level of accessibility for the motor car is worth having. Still, Marshall seems to overlook the main purpose of the Buchanan report, which was to analyse the consequences of bringing heavy car use into different types of urban area. He makes little reference to the Buchanan report’s critical views on the redesign of existing cities to large scale road building.

This lack of proper recognition of the Buchanan report seems connected with Marshall leaving out of his discussion the important topic of car traffic volume in urban streets and the concept of “environment capacity” which was central to Buchanan’s analysis. We will return to this later in our paper.

Few will disagree with Marshall that the main challenge “is to address the street as an urban space as well as a movement channel, and how to make this conception of the street work – not just as an isolated architectural set piece, but as a contribution to wider urban structure” (p.15).

But Marshall stresses that we must go “beyond the rhetoric of good intentions” and go “beyond the recognition that streets are for people”. He states that his book aims to tackle the “unchallenged truths” in issues such as “circulation, spatial organisation and underlying structures, and
not just superficial form”. The issue of hierarchy of road networks is an important topic that Marshall deals with.

To reach his aim, the book takes two basic strands: The first is to analyse the “design debate”, which is the most practically oriented part of the book (chapter 2). This is the source for most of the following paragraphs. The second, and dominant part of the book, is a theoretical analysis of the “nature of structure” (chapters 3-7). The final chapters (8-10) suggest practical applications of his analyses. We return to his analysis and proposals in the next main chapter.

First we concentrate on Marshall’s problem description. His analytical tools and proposals for an alternative, more street-based approach will be discussed in the next main chapter.

Marshall observes (p.10-11) that the importance of transport for urban development and the form and structure of cities has been widely recognised for long, both by traditional urban planning and development and in modernistic planning schools of thought. It is the uneven balance between the considerations of circulation and place that has created the problems of modern city planning and transport development, he states. Reading the book we find the following main points of critique from Marshall against modern urban planning and street network design.

**Separation of circulation and place**

This Marshall calls “the cataclysm of Modernism”. The modernistic concept of vehicular highways separate from buildings and public spaces required a dramatic transformation of traditional urban form and city design. The close relationship between movement and urban place that had been the core characteristic of urban main streets, was inversed; movement in the form of fast motor traffic should be taken away, and the urban places should become tranquil precincts.

![Figure 10. Caricature of historic and modern settlement structures. (a) The historic structure with the market square as the central stage and focus of traffic intensity. (b) The modern structure with the main traffic flows and focus of interest directed towards the main road system outside the city (Marshall 2005, fig. 1.3).](image-url)
By this, the road system was turned inside out: Traditionally the central stage of traffic was the market square, and the intensity of circulation and movement dissipates outward from this core. In the modern structure, the main flows are on the high standard roads designed for fast vehicular traffic, and the former main streets become backwater access roads or pedestrian precincts. The same characteristic patterns are found in modernistic plans for urban blocks and street patterns.

Traditionally the circulation system formed the backbone of settlements. In modernism the road network is set up as a separate system.

“The disassembly of the street”
Modernism changed the traditional design of the street with house frontages and building entrances closely linked to the street form. The traditional street unites the three different roles of circulation route, public space and building frontage. Instead, streets and buildings were “liberated” from each other.

Roads could follow their own linear geometry suited for circulation, while buildings could be designed to fit their own, specific functional requirements and also stand out as separate, sculptural forms in the urban landscape, without a clear frontage and backside.

![Figure 11](image)

Figure 11. (a) Traditional fit of streets and buildings. (b) Roads and buildings follow their own dedicated forms and layout (Marshall 2005, fig. 1.5).

“The schism of Modernism”
According to Marshall, the modernistic separation of the elements of the street led to a division of labour and responsibility between the design professions. Transport engineers took care of the highways, road and traffic system and rail infrastructure, architects concentrated on the design of buildings, and landscape architects the open spaces between buildings, roads and railway lines.

The differentiation and segregation of road functions
Under the two last headings, Marshall claims that the principles of road differentiation and traffic segregation follow as a consequence of the disassembly of the street and the professional schism of Modernism. Since these principles are at the core of our study, we prefer to make this a separate point.
Without the traditional, integrated approach of street design, the transport engineering focus on circulation led to further specialisation of the different parts of the circulation network according to their transport functions. In good, modernistic manner each road would have a single, main function, and should be designed according to this function.

Referring to Traffic in towns, Marshall (p.7) claims that the classical street almost disappeared from official terminology. Instead, former streets were termed as distributors or access roads to specify their different functions in the road system. We can add that the same happened in the SCAFT recommendations. But in later Swedish and Norwegian road design manuals this was modified in order to take account of the traditional street, and in order to cater more properly for the urban place aspects, walking, cycling and public transport.

The fastest and highest capacity roads should be designed without direct-frontage access and with a minimum of intersections. The flow of car traffic on these roads should also be segregated from pedestrians and other non-motorised traffic. At the other end of the scale, access roads should mainly be designed as cul-de-sacs, in order to avoid through traffic in quiet, protected residential areas.

We note that Marshall does not discuss these principles on their own merits. We believe that this is a major flaw in his critique and leads to significant shortcoming of the advice on urban street network design that he puts forward.

“The disurban legacy”

Marshall, and several sources he refers to, concludes that the “roads and traffic-driven approach proved disastrous.” This is due to the urban
destruction and the disurban creation that followed from the engineering principles of road and traffic design.

By urban destruction he refers to the physical intrusion, demolition, severance and blight caused by the attempts to adapt the city to the dynamics of motorised traffic and road building. By urban destruction he refers to the highway-led approach as a formative influence on urban layout which resulted in “dull and dysfunctional layouts, where new development is lacking identity, vitality or urbanity”.

In this context he also indirectly reveals his definition of urbanity in a footnote (!): “Disurbanism is associated with the breaking of traditional relationships between buildings, public space and movement”.

**Rigid application of the standards of a hierarchy of roads**

Marshall acknowledges that the development of modernistic, highway-led urban planning and development has not evolved without opposition. But his presentation of the historical process of dealing with the rise of motorisation in the rich countries is inadequate.

His historical perspective does not take the reader further back than to the early 1990’s, when he refers to the “counter-revolutionary” movement of New Urbanism (in the US) and similar initiatives (in Europe?). He tells us that these movements have replaced the rhetoric of the motor age with the rhetoric of sustainability and neo-traditional urbanism. He claims that “compact, dense, mixed-use neighbourhoods are back in fashion…..The street itself, once seemingly in terminal decline, has undergone something of a renaissance. Street grids are back in vogue.”

He also connects this “counter-revolution” with the return of “neo-traditional transport policies” that favour walking, cycling and public transport. The “monolithic modernism” of highway engineering and car-oriented urban “solutions” is being replaced by traffic calming.

However, despite these changes in urban transport and planning ideology, Marshall claims that we still “find some familiar Modernistic principles still exerting a powerful influence on the layout of our towns and cities” (p.9).

Marshall criticizes the Buchanan report’s principles of urban layout and hierarchy of roads with different functions that still live on in current theory and practice. With these principles, he claims, we could not create the exemplary urbanism of traditional cities. According to the author, this failure of present urban and traffic planning is the basic stimulus and challenge of his book.

The core of the problem seems to be the rigid application of the codes of a hierarchical system of roads and their accompanying design standards, and the effects of these transport requirements on the fabric of cities, their land use and the form of urban development patterns and buildings.

A major part of Marshall’s book is therefore devoted to the analysis of the structure of street patterns in order to create a new conceptual framework for the development of good practice in urban design.
Mismatch between the urban grid of streets and the road hierarchy

In his chapter 2 Marshall discusses the challenges in more detail. Referring to two British planning design guides he points out that the main challenge is to solve the conflict between:

- the urban principles of street design, and
- the highway engineering principles of a hierarchical road network design.

The two different approaches create a mismatch where the role of the street, and especially the design of street grids, is unclear and without a consistent conceptual framework. Marshall’s aim is to reconcile this conflict or “the filling of the void with something positive” (p.22).

We note that he says that he does not attempt to deal with all aspects of street design, but focuses on the interface between the two points of view (p.23).

Marshall makes a brief overview of different types of road and street design advice that have been presented in the professional debate. He makes the interesting point that the prescription of recommended patterns of road and street networks has not been in the focus of highway guidelines (which deal with the design of different types of links and junctions), but has been a matter of concern for urban designers.

He also notes (p. 35) that some of the urban design guides include elements of hierarchical systems of urban streets and open spaces. “Hierarchy” is not necessarily a disurban concept, as one sometimes may interpret critics of current practice as saying. The urban planners agree that the conventional highway engineering hierarchy is “bad”, but they are unclear and inconsistent about what constitutes a “good” hierarchy.

Further, Marshall (p. 36) points out that the hierarchy and pattern of network is often confused and ambiguously mixed together. Later (p. 67-61) he mentions several problems connected with the classical road hierarchy definitions:

- Reduced diversity due to the designation of single main functions of the road or street.
- The dominance of specific traffic functions over all the other roles of the street.
- The criteria for route type definition in the road hierarchy are rather casual and subjective.

He sees a need to sort out the different meanings and implications of different kinds of tree or grid patterns and different types of hierarchy. Typical terms used by urbanists to describe the desirable network are coherence, clarity and legibility. Marshall notes (p. 30) that these qualities seldom are precisely defined. This leads to his ambition to analyse and depict the patterns and network qualities in order to be able to distinguish between “preferred” and “discouraged” patterns. He also comments on the fact that both verbal and graphic descriptions are open to interpretation and possible misunderstanding, even misuse by uncritical copying of so-called ideal examples.
Critique of certain network properties
Very briefly (too quickly for our subject interest) Marshall discusses (p. 36-38) the ongoing debate about preferred and discouraged patterns of street networks. The debate often boils down to a discussion of polarities between urbanist and traffic engineering recommendations, such as between:

- “permeable” grid network versus “closed” loop and cul-de-sac network
- dispersal of car traffic to many streets, versus concentration of car traffic on few streets
- X-junctions versus T-junctions

Marshall sees that in practice the conflicts are not so clear cut. He refers to studies of neo-traditional urban designs that liberally use cul-de-sac streets. And the merits of the grid from an urbanist point of view cannot be taken for granted. Camillo Sitte, one of the key sources of inspiration of the neo-traditional movement, argued against the use of crossroads (X-junctions), grid street network and monumental, symmetrical layouts.

Marshall even refers to Ray Brindle’s (1995) warning of “the dangers of transport planners and traffic engineers being seduced by the rhetoric of neo-traditionalist planners with their preference for the grid” (p.38 and chapter 2, note 38). Unfortunately, he does not go further into this debate, which is at the core of our study.

In the next sub-chapter we will show that even in the Swedish debate, the critics of the conventional road network design do not have a consistent view of the type of network solutions that should be chosen in a given context.

Principles of separation between mobility and access functions overlooked and excluded the traditional urban street
In chapter 3 Marshall discusses the conventional principles of road classification before he goes ahead with his analysis and recommendations for an alternative approach. In Britain he pinpoints the breakthrough for these principles to the Buchanan report (Ministry of Transport 1963) and earlier work by Alker Tripp (1942 and 1950), who was influenced by ideas from the USA.

Marshall mentions (p.50) that both Tripp and Buchanan were concerned about road safety and that Buchanan also emphasised environmental quality as his first concern, with car traffic in a subservient role. But he concludes that the road classification scheme advocated by the Buchanan report has often in practice lead to traffic-dominated outcomes.

Marshall points at one particular aspect of Buchanan’s proposals that can explain this result. This is the idea of recognising only two polarised types of space. With the rooms and corridors of a hospital as an analogy for inspiration, Buchanan stated the general principle of distinguishing between only two types of roads:

- Distributors designed for movement, and
- Access roads to serve the buildings.
Although Buchanan developed the road classification further with three classes of distributors, the one-dimensional criterion dealing with motor traffic lead to a road hierarchy where the various forms of traditional, mixed use urban streets did not fit in.

This is illustrated by the classic inverse relationship between the functions of mobility, or circulation, and access. In the conventional road hierarchy all recognized road types lie on a spectrum between 100 percent priority given to circulation and 100 percent priority to access. However, the most important urban street, the classic arterial street does not fit into this dichotomy at all.

![Diagram showing inverse relationship between mobility and access.](image)

**Little attention and low priority given to non-car modes of transport**

The last major point of critique we will mention from Marshall is the lack of interest of traditional road planning in the “sustainable” modes of transport, and the low priority given to these modes in the design of streets and the road network.

He calls for “*a more balanced solution to movement in towns and cities*” (p.192) and he argues that we should consider a large spectrum of transport modes. But the focus should be on “*the needs of people, whether inside vehicles or not*” (p.192).

It is our opinion that much of Marshall’s critique on this point is rather outdated. We feel that he does not recognise what has taken place in urban transport policy and traffic planning the last 30 years, and the significant effort that has been made to “civilize” the use of cars in inner cities. “Better towns with less traffic” was the title of an important OECD-conference in 1975 that summarized a number of case studies of alternative transport policy aiming at the improvement of the urban environment and life in leading towns and cities in the OECD countries. Since then, terms such as traffic calming, home zones, woonerfen, verkehrsberuhigung, quiet streets, car-free zones, bicycle towns, tram cities, and so on, have become everyday terms in the traffic planning professions and urban transport policy of many cities.

This does not imply that all is well. The modern societies’ ability to make use of the lessons from the environmental policy period of the 1970’s has
not been so impressive. Market economics, national and urban laissez-
faire politics, and global issues, moved attention away from the down-to-
earth politics of urban environment improvement that played a significant
role in the 1970’s.

It is therefore still easy to agree with Marshall that there still is a large
need for much further improvement of the networks for public transport,
cycling and walking. These modes should obviously have top priority
when we are designing transport for a more sustainable city.

**Key theoretical issues for resolution**

To overcome the various challenges and pitfalls mentioned above, the
bulk of Marshall’s book covers his development of some new tools of
network pattern analysis. According to Marshall, the tools are developed
in an attempt to resolve the following set of key issues (p. 40):

- The basis for street type definitions
- The connection between street type and hierarchy
- The identification and justification of “good” and “bad” hierarchy
- The distinction between hierarchy and pattern
- The identification of “preferred” and “discouraged” patterns
- The relationship between pattern and process of generation.

These points Marshall picks up at many places in his book. Nevertheless,
we still find it partly difficult to understand exactly what his practical
solutions are in response to all these challenges of theory.

### 2.2 The TRAST debate

We will now look at the debate that has taken place in connection with
the Swedish TRAST project aiming at updating and improving the
Swedish national guidance on urban network planning, street design and
sustainable city development. This gives the international and somewhat
theoretical debate, reflected by Marshall, a more down-to-earth flavour
and a connection to the debate about transport and city planning advice
on urban networks in Sweden.

The traffic network discussion in Sweden, as in other countries, should be
seen as an integrated part of a much wider debate about the quality of
urban living and the need to develop more sustainable transport systems
and settlement patterns.

The national Swedish planning authorities are active in this wider debate,
for instance through the publishing of books such as “Den måttfulla
staden” (The ecological city; Boverket 1995). In a recent publication in
English, Boverket (2004) asks us to “Make towns – instead of traffic
planning and housing development”. This publication highlights some
points of relevance to our discussion of the problems of the conventional
road network design.
The problems of the car society — exacerbated by road network design

The problem description of Boverket takes the form of a rather strong critique of post-WW2 policies in Sweden:

“During the latter half of the 20th century new town planning ideals, and the possibilities offered by the car, have led to the development of towns being characterised by thinning out and urban sprawl. Clarity and connection have often been lost. Housing, workplaces and other activities have been separated and the town divided into zones. This resulted in longer distances and heavier traffic. The town, which had been built for proximity, was now increasingly built for motorized mobility. For those who do not have access to a car, 25 percent of Swedish households, this development has involved considerable restrictions on daily life. The daily life of people is no longer the guiding principle.

The car quickly dominated the townscape. Traffic queues and parking also take up valuable space. The physical result has become a town of which large parts are a traffic landscape. Streets and esplanades have been replaced by traffic routes. Road junctions have become traffic roundabouts and broad traffic routes have been imposed on old town centres. Ring roads and large-scale traffic interchanges have been built in the newer areas. The appearance of the town has changed, in many cases dramatically” (Boverket 2004, p. 7).

As explanations for this dismal situation in one of the most well off, and most efficiently organised countries of the world (our characteristic), Boverket offers the following interesting points of explanation (our extracts):

– “The functionalist ideal of town planning dominated; space, light and air were to replace overcrowding, and neighbourhoods were to become self-supporting for schools and services.

– The number of cars increased dramatically. But the negative effects of traffic increased far more than did traffic itself.

– Those who moved to the new districts were mainly younger and middle aged people with children. Care of children became a strongly controlling factor as regards planning. One aim was to reduce accidents involving children through planning. And that was successful. But other values and qualities of the town were lost.

– The increased mobility offered by the car has generally resulted in proximity being lost. At the same time, public transport has not been prioritised; it and urban areas have not been developed in a coordinated way.

– Distances to service facilities have increased, not only in the countryside but also in the town. At the same time, the retail trade has undergone considerable change. Increased establishment of out of town shopping centres not only affects the town, but also its surroundings. Traffic in the town and traffic outside the municipality are both affected. For those who do not have access to a car, proximity to a bus stop and a shop mean a great deal. The disabled, women, old people and children are especially affected.
As towns have spread, children increasingly have to travel longer distances. This is connected with changed lifestyles. Sometimes, for example, they live in two places with separate parents, and they can have various activities spread around the town. Heavier traffic also means that parents feel uneasy about the possibility of their children being in an accident. Therefore, those that can, increasingly give them lifts, driving them about.

But travel for pleasure has also increased, in pace with improved living standards. At present, leisure trips constitute about half of all travel, irrespective of whether calculated in number, time or length of trip.”

It is easy to see that this complex problem situation cannot be solved only through a change in the planning and design practices of urban road and street networks. A much wider perspective is needed, and Boverket recommends us to do away with separate traffic planning altogether!

**No more traffic or housing planning, only town planning and design**

According to Boverket (2004) the division between housing development and traffic planning, which rules today, is extremely unfortunate. This explains the publication’s appeal for integrated town planning, design and development.

The problem, as described by Boverket, is that the modern society has based it’s mobility on the motor car, and that this mobility has been exploited to create new residential, work, service and recreation structures and travel habits. The negative consequences for the environment and city life have been aggravated by the way cities and urban transport has been adopted in order to have these benefits without too large losses of life and limb, in particular by concern for the safety of the youngest generations.

Our judgement is that this is a rather simplistic set of explanations of a very complex social development process. It is obvious that a very broad perspective and debate is needed if society wants to turn around the trends of increasing motorisation.

One should, however, not forget that a range of serious social and environmental problems, particularly in the housing sector, was overcome by the urban policies that were carried through in Scandinavian towns and cities in the period 1945-1975. It is important that the great benefits of housing qualities, strongly reduced accident risks in the transport system, and safer environments for children and the elderly, are not lost in the debate about ”creative” city structures and flexible transport networks.

We can also see a need for more exact analysis of the cause and effect relationships that are often implied between the problems of the car society and the type of road and street networks – and building forms and patterns - that have been designed.

One might in many cases ask: Would the problems of car traffic be less serious to-day if we had not changed the road structure, and more or less kept the network as it was in 1960? A quick look at the third world cities of to-day, should give some food for thought.
Asking for more scientific evaluation of principles of network design

Anders Hagson at the Technical University of Chalmers, Gothenburg, stands out as one of the most outspoken critics of the conventional approach to road planning and traffic system design in Sweden in later years. His study (Hagson 1999 and 2000) of the historical antecedents and knowledge base for the SCAFT recommendations and later Swedish guidelines on the design of urban traffic systems started off a still ongoing professional debate.

Hagson is very sceptical to the four SCAFT planning principles of traffic segregation, traffic differentiation, environmental areas without through traffic by cars, and the idea of a simple and an easy-to-read traffic environment. He claims that these principles have a very weak (close to none) scientific foundation. He argues that the SCAFT principles are counter-productive in relation to the goals of a sustainable society with priorities for improvements in environment, traffic safety, universal accessibility, economic development and more attractive and livable urban areas.

His critique is very similar to the points mentioned by Marshall and summarized by us in the former sub-chapter. He describes the historical antecedents of these principles we have already mentioned, but adds one important point of critique: Much of the conventional planning advice, he claims, has no scientific or empirical basis. In particular, he demonstrates that the influential SCAFT recommendations in the 1960’s and 1970’s at his own University, were based on very little, and weak, empirical evidence.

The problem is, however, that Hagson himself does not offer much factual evidence to support his recommendations of alternative principles of transport system policy and design. We will come back to this in the next chapter.

Further, Hagson (2000) argues that the conventional approach to urban development and road network design has aggravated the problems of energy use for transport, traffic accidents, noise and pollution, as well as the problems of accessibility for the carless and the degradation of the urban environment. This is caused, he claims, by ten “anomalies” built into the SCAFT principles (Hagson 2000, chapter 9.2). We will comment on some of his most important points in relation to the design of the urban transport network.

The extensive road hierarchy creates more car traffic and stimulates urban sprawl and less sustainable traffic – but what about traffic safety?

It is easy to agree in principle with Hagson about his two first anomalies, which deal with the land use effects of the highly differentiated road system. SCAFT’s extensive hierarchy of roads lead to the building of large, expensive, land-consuming road constructions, much left-over space inside the traffic system and large protection zones. These road systems are often badly adjusted to the needs of pedestrians and cyclists, and the routes for buses become long, winding, time-consuming and costly to operate. This creates more car traffic and, because of this, the problems of traffic safety and environment are aggravated. In addition,
the new, improved main roads for cars in the differentiated road system created new incentives to car use and stimulated urban development along the new highways. It seems clear that one important effect of the extensive road hierarchy is to make the transport system less sustainable in the long term.

However, we are not ready to conclude, as Hagson does, that the increase in car mileage due to the road hierarchy is so large that the total effect of this network solution is to create more traffic accidents. As we will see later in this paper, the channelling of car traffic onto modern roads designed for traffic safety reduces significantly the accident risk in relation to the vehicle-kilometres travelled. The two factors of increased mileage and reduced risk work in opposite directions, and when we look at the historical development of accident figures in the Scandinavian countries, there are clear indications that the net effect has been very positive as far as traffic safety is concerned. However, to make a definitive conclusion, more detailed investigation is needed.

Too little understanding of the ideas behind neighbourhood units and environmental areas

Hagson attacks the conventional (and SCAF) planning idea of the neighbourhood unit with grouped local services at walking distances of dwellings within environmental areas without through traffic by cars. His point is that people living in a housing area that is physically organised like the neighbourhood unit, does not necessarily have a pattern of local movement and activity that makes this type of urban design an instrument for reducing the amount of travel and car use that people have.

According to Gallion and Eisner (1963) this is a common misinterpretation of the original idea of the neighbourhood concept. The neighbourhood unit is not a sociological phenomenon or a theory of social science, but simply a physical environment in which residents, in particular children and their families, can have a safe living environment. Families can live protected from through traffic, without the constant anxiety of traffic accidents in the more heavily trafficked roads and streets, and with safe routes to schools and local services and comfortable and attractive roads for walking and cycling. Even a reduction in the use of cars for short, local journeys may be hoped for.

In his eagerness to tell us the obvious that people in an urban area very often make many moves across the main streets and roads during the ordinary, daily life, Hagson seems to overlook both the initial idea of reducing risks of traffic accidents for children, and the practical and economic advantages of environment areas that concentrate major traffic volumes to a small number of main roads and streets.

Both traffic safety and noise problems are much easier to solve if the main sources of disturbance are not dispersed, but concentrated to corridors where alleviating counter measures will be cost-effective. And by concentrating traffic to the least sensitive routes, the need for such measures may also be minimized.

Hagson claims (through his anomalies number five and six) that such less sensitive traffic routes are difficult to find in existing cities, but we
disagree. Urban areas and road and street networks are inhomogeneous, and there are often large variations in the land use functions, building types and densities of exposed people along different parts of the network.

The objective of a sustainable transport system is not only aiming at global issues of energy use and climate change, but must also deal with the local effects that more directly disturb, and often very seriously hurt the urban population, such as traffic safety and feeling of security, noise and local pollution. One must also consider the health-critical opportunities for play, walk and cycling that the environment area of the neighbourhood unit supports.

**The challenges of the arterial main streets**

Although we judge Hagson’s arguments against the neighbourhood unit and the environmental area to be very weak, we share his scepticism of applying SCAF’s main road design solutions on major arterial urban streets.

However, SCAF’s way of thinking about the busy, multi use street environments of cities, towns and villages has been almost out of the question of modern traffic planning for the last 20 or 30 years, although it has taken some years to find the right design solutions for this type of complicated traffic and urban place situation. The ARTISTS project summarizes the state of the art, and is studied a bit closer later in this paper. So, in relation to today’s planning and design practice, Hagson is hitting at a wide open door.

**Underrated benefits of pedestrian and cycle routes separate from car traffic**

The seventh and eighth anomalies of Hagson (2002) deal with the separate roads for pedestrians and cyclists that are recommended by SCAF, i.e. the principle of traffic segregation.

We agree with Hagson, as well as with Jan Gehl (1980/87), another critical observer of the urban environment, that the principle of segregation has inspired the creation of many dull and quiet walkways, which tend to be unpopular route choices for many of the intended users, in particular in dark and/or bad weather.

Hagson refers to a twenty-five year old Norwegian study that showed that pedestrians and cyclists are sensitive to the design quality of the roads, both details and the overall connections and alignments they offer. Also many other, more recent, studies not mentioned by Hagson have shown that badly designed traffic solutions for cyclists and pedestrians will not be used.

However, this does not mean that the principle of segregation is completely dysfunctional. Existing design guides that aim at improving conditions for walking and cycling emphasize the need to combine mixed traffic streets and roads with separate roads and paths into a complete and dense network of routes. Again Hagson underrates the positive aspects of the environment areas without through traffic and the benefits of car-free roads and paths for the non-motorised, environment friendly modes of
transport. We return to the documentation of these effects in later chapters.

The conflict between simplifying traffic environment and speed reduction

Hagson’s final two anomalies are much more appropriate. He makes a good point by reminding us that the SCAFt idea of traffic environment simplification is in conflict with the modern principles of traffic calming by design. Simplifying the car driver’s environment may perhaps make it easier for the driver to perceive the traffic and more easily observe and understand the behaviour of other drivers, pedestrians, cyclists etc. But drivers tend to make use of the feeling of greater control of the situation to drive faster, which leads to a rise in accident risk.

Research on the effects of traffic calming and the effects of street design on the speed of car traffic confirms that drivers adjust speed to sight conditions along the street or road. Current advice on traffic calming by street design reflects this fact. So, it is easy to agree with Hagson that traffic speed should be kept down in order to secure a high level of traffic safety in urban areas.

But Hagson takes this one step too far when he claims (p. 203) that the problems of car traffic in mixed use streets only become serious when the speed of driving is high. As we will discuss later, the environmental, urban problems of car traffic are strongly related to a number of other factors than speed, such as traffic volume and composition, where the heavy traffic runs in relation to urban activities, the design of streets and buildings, the share of traffic space between different users, etc.

We will return to a discussion of Hagson’s recommendations in the next chapter. We will also look at the research on the effects of car traffic in different urban street environments. Before that, we will briefly comment on one last document that most clearly express a critical view of the city structure and urban traffic network that dominates much of Sweden’s towns, cities and villages.

City-friendly traffic planning requires that car accessibility should no longer have top priority

In a booklet sponsored by the Swedish Roads Administration, as part of the TRAST project, also Lagerquist (2000) forwards a strong critique of conventional traffic planning. His contribution is inspired by the increased political, popular and professional interest in, and demand for, more attractive and lively cities in a society of long term ecological, social and economic sustainability. His focus is mainly on the new types of multidisciplinary planning and public participation that should take place, and the new types of transport and urban planning policies that are needed.

However, at several places, Lagerquist also mentions the principles of the urban transport network design. He sees the following aspects and elements of the traffic system as problematic in relation to the values mentioned above:
The car society has impoverished urban environments, divided up the city by heavy traffic and the barriers created by the highways’ right-of-way, and also stimulated urban sprawl.

Walking, cycling and the use of public transport must increase at the expense of car use, and the structure of roads and transport policy must change in order to facilitate this.

Car traffic should be reduced to a level that the city environment and street activities can tolerate.

The functionalistic, dendritic (tree-like) road network with cul-de-sac access roads should be done away with and replaced by more traditional grid networks.

To us, the points about transport policy have been rather conventional wisdom for many years. The critique of the cul-de-sac road is a common theme in the critical professional argument dealt with in more detail by Marshall (2005).
3 Analysis of current proposals and recommendations

3.1 Proposals by Marshall - Streets & patterns revisited

After this overview of the problems of the conventional “car-oriented” urban land use and transport planning approach, as seen by the critics, we will study more closely the alternative proposals and recommendations the critics have presented as better “solutions”.

First, we return to Stephen Marshall (2005). We study the analytical tools he has developed and the recommendations he puts forward for the future urban planning and design of urban road systems. Finally we summarize our critique of Marshall’s argument, in order to create a platform for our further investigation.

As a reference and help to our own understanding of Marshall’s analysis, we have made a short description of his most important concepts and analytical tools in an appendix. Among these are the concepts of connectivity and complexity, two aspects of networks that he manages to quantify in relative terms in order to compare these qualities in different networks.

Preferred network structure in relation to connectivity and complexity – neither tributary, nor grid network

Marshall concludes (p.154-55) that a so-called “characteristic” structure, with a medium level of connectivity and a high level of complexity, is typical of traditional street patterns. This is the network structure that has the quintessential street pattern shape that the urbanists recommend. It can be described and measured with the analytical tools Marshall has developed, and this characteristic pattern is clearly different from both tributary and grid networks. A few examples from the book are given in the appendix.

Our interpretation of Marshall’s conclusion is that if you want a traditional street network, then you should design networks that have a medium level of connectivity and a high level of complexity. But you should avoid tributary or grid networks, which both miss out on the requirement of complexity. We note that, contrary to what is often claimed in the debate, the grid is not necessarily the “best” network solution, as interpreted in Marshall’s analysis.

Preferred network structure in relation to constitution

In chapter 7, on the constitution of structure, Marshall concludes the theoretical analysis by distinguishing between different types of network structure. The term constitution refers to a system of types and relationships in the form of a street hierarchy that is an abstraction of the network configuration. This, in turn, is an abstraction of the actual network composition.
The constitutional structure is defined through the street properties of arterality and access constraint (p. 171-174). Arteriality implies that each route must connect to a route of the same or higher status. The pattern of arterial routes forms a complete network of contiguous\(^2\) links. With access constraint the continuity is broken.

Four types of constitutional structure are identified, and the illustrative table shows the different combinations of structural conditions that create these types of networks\(^3\):

**The dendritic structure** is formed by the combination of arterality and access constraint. This structure is typical of the modernistic, disurban road networks that the neo-traditional urban planners, and Marshall himself, criticize.

**The conjoint structure** is based upon arterality without access constraint. This is typical of inter-urban networks and traditional settlements where all streets and roads join up.

When the arterality condition is lost, two other types of network structure are possible:

**The mosaic structure** has no access constraint, and lack the degree of organisation that is needed to ensure arterality. The term “mosaic” is used to imply that the structure consists of distinct bits and pieces with no particular order.

**The serial structure** is formed by access constraint between major and minor routes via an intermediate level, but without arterality due to the lack of contiguous connectivity between the major types.

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\(^2\) In Norwegian: Contiguous = tilstøtende, sammenhengende

Marshall goes on to characterize the four constitutional types of networks by the use of five “desired properties”:

- Coherent pattern; i.e. a consistent constitution over the whole network under study (conjoint, mosaic, or other).
- Legibility; this Marshall interprets to require arteriality, and hence the “minus” for the mosaic and serial types of structure.
- Clear typology; i.e. the existence of clearly recognisable types of routes.
- Clear hierarchy; i.e. a clear order of routes connected in consistent ways; hence the minus for the mosaic structure.
- Less rigid hierarchy; i.e. anything than the dendritic structure.

An urban designer’s “good hierarchy”, he claims (p.176), is one in which streets play a “satisfactory” role and are not just defined as access roads. According to Marshall’s analysis, the only structure type that fulfils all the five mentioned requirements is the conjoint structure.

However, it is an important demonstration made by Marshall that the network property of hierarchy is different to the constitutional structure. All four structures may have a hierarchy of streets or links or open space defined for them, and the criteria of definitions for the different levels should vary according to the purpose of the classification.

**The structures of car orientation and disurban creation**

At the end of chapter 7 Marshall uses his tools of analysis to characterize the structural properties of the car orientation and disurban effects of modernistic road network design. His main conclusions are (p. 179-187):
The dendritic constitution may to some extent be equated with “bad hierarchy”. Such a hierarchy “is fine for cars” (p. 187; i.e. car users!), but dysfunctional to the public transport system and pedestrians (and cyclists, we may add). Access constraints is useful in the car system, but should be avoided as dysfunctional in the pedestrian network, and to a large extent also in the public transport system.

The lack of continuity in the pedestrian network and between the pedestrian and public transport networks contributes to the car orientation of existing structures.

In relation to the disurban creation of a wasteful, desolate road structure and dismal, un-urban layout, Marshall finds (p.184) that it is not the dendritic structure as such that is the problem, but the manner in which the streets are fitted in the hierarchy. He illustrates this by comparing the networks of two different new towns, the supergrid of a modern new town and the street network in Craig’s New town in Edinburgh.

Figure 16. The public transport system creates a network with conjoint constitution (Marshall 2005, fig. 7.15).

Figure 17. Two different dendritic structures: (a) The classic, urbanistic grid of Edinburgh New Town. (b) The supergrid of a modernistic new town (Marshall 2005, fig. 7.19).
The difference lies in the ranking of routes by arteriality. In the traditional plan “all the main streets connect up, focussing on the main square. In the modern case, arteriality ranks traffic routes; it is the national traffic network that links up contiguously” (p.184). Marshall (quite rightly) points out that in the road hierarchy recommended by the Buchanan report, streets would only be at the bottom level of access roads in the hierarchy, while several levels of distributors was recommended between the access roads and the primary distributors.

The implication we draw, is that urban layouts require that streets also should have a significant role to play higher up in the car network hierarchy. This, indeed, is also the implication in Marshall’s final discussion of the resulting networks he recommends (the “tartan” networks in chapter 9).

**An articulated route hierarchy based on speed and transit hierarchy**

In chapter 8 Marshall deals with the obvious fact that “the design of roads and streets is strongly influenced by the modes of movement that use them” (p. 191).

He first discusses parameters that may describe favourable and less favourable transport modes, and creates a mode classification (the “modegram”, p. 199) that includes a number of exotic modes (e.g. dog-sledge and elephant for several persons), but which turns out to be a sidetrack from the main analysis of network structure and design. He also ignores the important parameters of vehicle and route capacity and traffic flow. We will return to these aspects in our later comments.

However, Marshall’s next suggestions are clearly more useful. He formulates a proposal of a route hierarchy based on speed of travel and vehicle operation, which in principle is independent of mode. The speed classes are defined in the table.

<table>
<thead>
<tr>
<th>Speed</th>
<th>Examples of modes of movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>S5. Very high speed</td>
<td>Train, fast motor movement on motorway, busway, etc.</td>
</tr>
<tr>
<td>S4. High speed</td>
<td>Speeds attained on partially segregated rights of way, and on free flowing suburban main roads; the highest speed for a carriageway associated with a footway or urban street</td>
</tr>
<tr>
<td>S3.5 Medium-high speed</td>
<td>Medium-high speed motor transport movement</td>
</tr>
<tr>
<td>S3. Medium speed</td>
<td>Medium speed motor transport movement</td>
</tr>
<tr>
<td>S2.5 Medium-slow</td>
<td>Running; cycling; medium-slow motor movement</td>
</tr>
<tr>
<td>S2. Slow</td>
<td>Jogging; slow cycling or very slow motor movement</td>
</tr>
<tr>
<td>S1.5 Very slow</td>
<td>Walking pace; cycling or parking at walking pace</td>
</tr>
<tr>
<td>S1. Walking speed</td>
<td>Slow walking pace</td>
</tr>
</tbody>
</table>

Figure 18. Route classification by speed of travel (Marshall 2005, table 8.3).
The speed classes are defined so that a single street may consist of several speed bands, thus defining a quite extensive range of possible street and route types. The typical, normal street section will have the very slow speed band at the edges close to the buildings or other land use outside the street, and faster speed bands towards the middle of the street. This is seen to minimise conflicts between different users of the street.

Marshall combines the speed hierarchy with a proposed classification of transit-oriented arteriosity. By this he means a hierarchy of routes for all modes, arranged according to the requirements of public transport provision and arteriosity. This classification of routes sees the routes for the various individual means of transport (foot, bike, car, etc) as feeders or distributors for the public transport network. The public transport modes form part of the same hierarchy according to their role as local distributors, intra-urban connections or regional, national or international services. The transit-oriented hierarchy is defined in the table below.

Table 8.5 Transit-oriented hierarchy

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Types</th>
<th>Typical examples of modes of movement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Foot</td>
</tr>
<tr>
<td>A</td>
<td>Arterial/trunk route</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Sub-arterial route</td>
<td>●</td>
</tr>
<tr>
<td>C</td>
<td>Local distributor</td>
<td>●</td>
</tr>
<tr>
<td>D</td>
<td>Access road</td>
<td>●</td>
</tr>
<tr>
<td>E</td>
<td>Narrow lanes</td>
<td>●</td>
</tr>
<tr>
<td>F</td>
<td>Footpaths</td>
<td>●</td>
</tr>
</tbody>
</table>

Notes
Car, etc. = private motor including car, taxi, goods vehicle, coach.
Bike, etc. = bicycle and other human-powered vehicles.
In some countries, motorcycles and mopeds may use routes for two-wheelers in general; in others they are confined to networks used by private motor traffic in general.

Marshall then suggests a new “articulated” hierarchy of routes for the network defined by combining the two separate dimensions of speed and transit-oriented arteriosity. The hierarchy is described in the next figure.

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4 Norwegian: Articulated = leddet.
According to Marshall this new hierarchy promotes low speed solutions, hence walking and cycling, as well as public transport at all levels of speed. In addition, the classification has the important quality of being able to incorporate a large number of alternative types of streets and routes which are needed in practical transport planning and urban design.
An ordinal urban street space classification

After the proper incorporation of the non-car modes of transport in the route classification system, Marshall adds the dimension of urban place as a separate parameter of network and street design (p.211+).

The articulated hierarchy relates to the right of way of circulation. This must be balanced with the “right of place” that takes care of the non-movement aspects of urban street space. With the lack of any agreed, objective parameters to characterise and evaluate urban place, Marshall suggests the use of a subjective, ordinal ranking of street sections according to their significance as an urban place.

The intention is to “capture the relative significance of a locality, in terms comparable with arterial significance, that is, as an ordinal ranking related to geographical scale” (p. 211). The ranking will be up to the planners and decision makers, but should nevertheless be done “systematically and transparently, in a way that allows the relative significance of a locale or street section in its urban role to counter-balance its significance as an artery, on rather similar terms” (p. 212).

Marshall does not go into detail about the type of criteria or judgments that should be made on behalf of the urban places. As examples of place qualities that might compete with the arterial criteria, he mentions:

- A street that is one of the city’s top ten most important shopping streets
- An area of intense pedestrian activity
- A civic centre
- A town’s central square or central park

The main idea is that places of national or regional status are higher ranked than places of city importance, which in turn are ranked above places of district or local significance.

An urban street typology

By combining the two independent dimensions of arterial connection and urban place Marshall creates a classification system that echoes the classical dichotomy between mobility and access functions, or between distributor roads and environmental area. But now they are considered to be two independent dimensions, and this creates a framework for the classification of any type of street. Then he transforms the articulated route hierarchy to an ordinal scale to match the ordinal scale of the urban place dimension.

A particular street will tend to have a constant arterial status along its length, while having a varied urban place value. This means that the network consists of arterial routes classified by speed band and transit-oriented hierarchy, which can be divided into a “mosaic” of streets sections with different urban place qualities.

According to Marshall (text to figure 8.20, p. 217), this street typology allows for any type of street or road to be classified in relation to “any kind of form, use, relation or designation. As long as each street type is integrally coded for speed and arteriality, it will automatically fit the articulated route hierarchy. There are two rules: (1) Each route type
must connect to another route of the same or higher transit orientation; (2) Routes are stratified by speed,” with restrictions on speed differences at connections.

A constitutional rule system with seven minimum requirements, including land use relationship

In chapter 9 Marshall presents different network design approaches, which he associates with different ways of presenting design guidance:

- A composition approach would present existing plans to inspire new applications.
- A configuration approach would give design guidance in the form of explicit abstract configurations (e.g. a grid diagram) that are recommended.
- A constitutional-led approach would specify elemental types (e.g. links, routes and junctions) and their relationships, “without specifying any particular overall configurational (or compositional) outcome” (p. 225).

Marshall suggests a “constitutional” approach where the street is the basic building block of the design of urban structure and layout. He states that the detailed system of guidance would depend on the context of application, but outlines a “constitutional archetype” as a graphic devise of how the code or rules of the game of network structure design may be presented (Box 9, p. 231).

![Box 9. Constitutional Archetype](image)

He illustrates the use of this framework by creating a few potentially desirable network patterns, based on the idea of a flexible “tartan grid”, (example in fig. 9.22). This can very simply be combined with land use and building patterns within the grid structure to create any form of urban structure.
At this final stage of analysis Marshall adds another dimension to his classification scheme, in addition to the parameters he has developed concerning the transport and route network functions and the urban place dimension. He includes land use factors, defined as “frontage use” and “block composition”, into the code, and he also formulates an urban design criterion as “building and spatial relations”, referring to the overall arrangement and form of buildings in the shaping of street space.

Table 9.1 specifies the seven rules of code that Marshall suggests as the basic elements of an integrated street-based constitutional approach to network design. According to Marshall these rules seem to represent a minimum of design and planning conditions to generate urban layout.

<table>
<thead>
<tr>
<th>Sphere</th>
<th>Code rule</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport/route network</td>
<td>1. Modes</td>
<td>Allowable modes coexisting along a street</td>
</tr>
<tr>
<td></td>
<td>2. Arteriality</td>
<td>Necessary connections between route types</td>
</tr>
<tr>
<td></td>
<td>3. Access constraint</td>
<td>Allowable connections between route types</td>
</tr>
<tr>
<td></td>
<td>4. Connection type</td>
<td>Allowable junction types between route types</td>
</tr>
<tr>
<td>Land use</td>
<td>5. Frontage use</td>
<td>Allowable compatible uses to adjoin each route type, to create street type</td>
</tr>
<tr>
<td></td>
<td>6. Block composition</td>
<td>Allowable compatible uses to adjoin each other, to create block type</td>
</tr>
<tr>
<td>Urban design</td>
<td>7. Building and spatial relations</td>
<td>Overall arrangement and assembly of buildings, form and massing within blocks, across blocks and shaping of street space</td>
</tr>
</tbody>
</table>

Figure 23. The minimum design requirements to generate an urban layout (Marshall 2005, table 9.1).
Implications for planning and design practice

In the concluding chapter Marshall summarises some practical implications of his analysis and recommendations.

His first conclusion is that when the fixed assumptions of conventional network planning are unlocked, a multitude of alternative street types, hierarchies of routes, ways of classifying modes, and types of network structures are available. By scrutinising all these alternatives, it is possible, he claims, to decide upon which assumptions and relationships should be chosen as a basis for the planning and design of urban network structure.

The opening up of these possibilities can take place by abandoning the inverse relationship between mobility and access, and replacing it with a three-dimensional coding of streets and patterns based on speed, transit-oriented arteriality and an urban place ranking.

However, Marshall recognises the need to work out the detailed rules of the proposed system of coding, “tailored to individual contexts of geography and professional specialisms” (p. 249).

He also points at other strands to follow in future studies and planning applications (p. 250+):

– The concepts and devices for identifying and analysing and expressing network structure, street types, modes, etc. could be further refined and developed.

– The findings of the study could be “plugged” directly into urban and street network design guides (this is what we are discussing in our study).

– The study suggests a “constitutional approach” to the design of urban streets and networks, and Marshall suggests that a more detailed typology of urban form (squares, terraces, etc.), design codes for building types and planning codes for frontage use, should be developed to be combined with his approach into street types. He envisages a single system of design guidance for a city or country.

– National and municipal guidance on roads and street types should be revised to reflect the reformulated hierarchy based on the street at the core of an integrated system of urban design. This could be “crystallised” into a single manual for streets covering all infrastructural aspects of street design.

– The theoretical concept of transit-oriented arteriality should be interpreted and expressed in practical terms, considering a number of issues, such as the definition of an optimal public transport network (our own point), securing appropriate connections between access modes and different levels of public transport services, solving operational conflicts in streets and at junctions, etc.

– The study suggests a new approach to town planning, where the core topic of planning is not land use (in various typologies), but where the streets and their network is the basic unit of urban development and design. This idea should be further investigated to provide a bottom-up approach to town planning, as opposed to the traditional top-down approach that starts with the idea of land use for the whole town or city as the unit of design.
Marshall’s approach, he claims, will facilitate the evolution of new modes, and new combinations of modes of transport in the future city. Future streets should and will reflect the new transport solutions, and could open up discussions of ideas such as covered, public transport shopping malls, bicycle boulevards, fan-assisted cycle tunnels, rollerblade arcades, etc. He suggests a three step phasing of a possible, incremental introduction of new, and more sustainable and urban transport networks for the future.

### 3.2 General comments on Marshall – some points for further analysis

In our opinion, Marshall’s book is a rather impressive piece of work, dealing with a series of interesting topics that must be covered in a thorough discussion of urban street and network planning.

The most innovative part is his analysis of route and network properties and structure. The analytical tools are interesting and may open for greater understanding of the meaning of network structures and patterns.

Marshall’s analysis is very well illustrated and presented. Still, we must admit that it took us some hours of hard work to grasp the meaning of some of his concepts, and their implications for solving the problems he pointed out in the beginning of his book. We hope our summary in this paper is a fair representation of his most important points of analysis.

We also agree with most of Marshall’s suggestions (in chapter 10) for further work, and would like to see this paper as a small piece of follow up work on one or two of the questions his analysis leaves open.

However, we also have a number of critical views on Marshall’s analysis that we will present in the following sections. We make these comments partly to contribute to the further discussions that Marshall calls for. But the main purpose is to set our own little piece of investigation on the right track, by pinpointing the “holes” in the analysis that we will go more deeply into in our next main chapter.

### Some comments on the analytical concepts and tools of analysis

First we will draw attention to some problems and challenges created by Marshall’s terminology and schemes of classification:

Marshall provides us with apparently objective, quantitative data that comes from the analysis of continuity and complexity of the network structures. The definition of routes in the networks is basic for his analysis. Very appropriately Marshall makes it clear that in practical application this definition is subjective and contextual, although he gives some advice on how to make the necessary choices when routes are defined.

We have not made any effort to test how dependent Marshall’s conclusions are on his route definitions. Although such an exercise might be intellectually stimulating, we doubt that an answer to this question will contribute significantly to future advice on network planning and design.

However, the point about the subjective nature of routes reminds us that one must be careful when comparing different networks, and certainly when the network descriptions are taken from different sources. When
analysing networks with the tools provided by Marshall, one should always check that the networks really are comparable and not a result of different types of route definitions.

It is also interesting to note that when Marshall gives advice on how the route definitions should be made, he refers to the car traffic system’s definitions of road classes and numbers, car traffic regulations at junctions, how the junctions are designed in relation to car traffic, etc. Although he later introduces his interesting concept of a transit-oriented hierarchy, this does not have the same power of network structure definition as the car system.

At times, Marshall’s terminology is confusing. Understanding the concepts of connectivity and complexity is complicated by the use of the same terms on two different levels of analysis, both as main parameters of network analysis and as one of the three parameters to characterize the level of connectivity or complexity. For complexity he also uses the term heterogeneity, and one might ask why he does not consistently use that as the common term for recursivity, regularity and complexity5.

Unexplained value judgements
Some places in his analysis Marshall makes value judgments that remain unexplained to the reader.

He does not clearly describe why the so-called “characteristic structure”, typical of traditional street layout networks, is to be recommended. His analysis shows that this type of network has a higher level of complexity than both tributary and grid networks, while still being able to offer a reasonable, medium level of connectivity. But he does not explain why the highest level of complexity is a desirable property of urban networks.

Neither does Marshall give much explanation of the five desirable properties of network structure (in table 7.5, p. 177++). He does not tell the reader why we should prefer networks with:

- Coherent pattern
- Legibility
- Clear typology
- Clear hierarchy
- Less rigid hierarchy.

These criteria he tells us he has developed from the “nature of the structure for the design debate” (p. 176), but he does not let us go more deeply into this synthesis. Perhaps we should study the urbanistic critique of the highway hierarchy approach more thoroughly to look for better explanations?

Marshall’s interpretation of at least some of these criteria must also be questioned. He connects legibility with the arteriality of the road system, but seems to overlook that the existence of a clear and continuous road system for cars does not help the pedestrian or cyclist or public transport user to “read” the network structure.

We must ask: From whose perspective is the network clear and legible? Strangely, Marshall seems somehow stuck with the “car driver perspective” of the traffic system and urban structure that still seems to dominate the debate about urban network design. Improvements at this point might be a follow-up topic for the further development of Marshall’s transit-oriented hierarchy.

Too many classifications and separate pieces of analysis?
One reason for finding it hard to follow Marshall’s argument all the way through the nearly 300 pages of the book, is his inclination to create classifications of a lot of different aspects and concepts, even when the schema contribute little to answering the main questions he rises at the beginning of the book.

We appreciate his creativity and insistence on braking down the concepts into their constitutional parts – that is good analysis in an intellectual treatise. But in this case some of the separate themes of analysis take place and concentration at the cost of the synthesis that is needed for most practical purposes.

One example: Marshall’s classification of modes (table 8.2 and the “modegram” in fig. 8.4) might be theoretically interesting, but apparently does not bring us any further on the topic of network structure and design of roads and streets. His analysis ignores the very important parameters of vehicle and route capacity, which are at the core of why public transport is an interesting mode of transport.

On the other hand, there are some other key topics that Marshall does not even touch upon, even when they are crucial for the development of guidance on the design of urban streets and transport networks. The most important omission, as we see it, is Marshall’s negligence of route capacity and traffic flow, and the effects of these factors on transport quality and urban life. That these key parameters in the design of urban transport networks are ignored is the most important point in our critique of Marshall’s analysis.

More questions than answers
Does Marshall answer the key issues he raises in the beginning of the book? Our judgement is that he has come some way by throwing light on the properties of network structure, and helping us to analyse network structure in a systematic way.

However, since he has not looked at how roads, streets, transport modes and urban spaces function in practice, with all the muddle of people and activities and urban furniture and space requirements of cars and other vehicles, etc., he has not been able to tell us what is really “good” or “bad” practice, or why some patterns are to be “preferred” and others should be “discouraged.” Perhaps that is too much to ask for.

In the first couple of chapters Marshall formulates a sharp critique against so-called modernistic urban network planning. Much of this critique probably most planners and decision makers of today would applaud.
But at the end, we still do not know much about the whys and whats of a recommended strategy that would be clearly better than the best of current planning and design practice.

To a large extent, Marshall’s analysis raises more questions that it answers. By this he has found a place in a solid, and appropriate, academic tradition.

**Mixing network and building structure?**
The critique of modernistic urban planning in general, as well as in Marshall’s well formulated version, embraces at least two different aspects of urban structure and design.

It is partly a critique of urban network planning based on a rigid application of a road hierarchy primarily designed to cater for the modern explosion in car use. But it is also a critique of modernistic building and urban design, which abandoned the idea of the traditional street with buildings closely related to each other, and replaced it with free standing buildings in an open, urban landscape.

With Marshall’s likening for the detailed brake down of the concepts of analysis, we could have expected that he analysed the possibilities of decoupling network structure from the form of urban buildings. At least in theory, it is possible to combine both traditional street buildings and free standing large buildings and smaller houses, with almost any type of road network structure.

The traditional street solution has its clear merits as long as car traffic volumes and speeds are kept low, more or less at the pre car-revolution level of the 1950’s in Europe and the 1920’s in the USA. However, the challenges of the full-motorised urban areas of today are very different. In practice they lie in the accommodation of parked and circulating vehicles, speed, safety, noise, air pollution, intrusion, etc. Or in a completely different transport policy option, where the car is renegaded to a second, third or fourth ranked mode of transport.

Marshall does not deal with these challenges of traffic and urban form. Instead, he takes it as given that the traditional street pattern is the most desirable structure even in the car age, and his central aim is to find the underlying structural characteristics of such network patterns.

**Neglected transport policy developments in the last 30 years**
Although the Buchanan report (Ministry of Transport 1963) is a central object of his critique, and referred to in many places in the book, Marshall does not go into Buchanan’s concern for traffic volume and his concept of environmental capacity. Buchanan’s focus (“Buchanan’s Law”) on the necessary trade-off between car accessibility and urban environment quality can, in our opinion, enlighten the analysis of networks in the car age.

Marshall recognises (primarily in chapter 8) that public transport, cycling and walking have been central in the debate on sustainable transport policy. But he does not take seriously the great extent these modes have been integrated into the planning of urban transport networks during the
last thirty years. Instead, he mentions how little attention the Buchanan report from the 1960’s gave to public transport and cycling.

This is a very appropriate remark in a discussion of the Buchanan report, but it is not an up-to-date contribution to the development of to-day’s urban transport networks. Now the debate must take account of the principles and experiences of modern transport policy and planning and design of streets and transport systems.

He criticises the rigid use of hierarchical road standards, but does not take much notice of the fact that the application of road design guidelines has been more flexible and varied in Continental Europe and Scandinavia since the mid 1970’s through the introduction of environmental traffic management, Woonerfs, traffic calming, public transport priority measures etc.

Civitas has analysed the contents of official guidelines for main street design in 15 different countries ⁶ (Haug, Havnen et al. 2002). In all countries studied, the design is open to planners’ discretion, although the degree of discretion varies. The definitions of urban main streets comprise widely different streets in terms of street widths and traffic volumes. The study confirms that the norm is to classify roads and streets into categories. Three of the countries and documents studied base the classification solely on transport function, but the majority classify streets according to a combination of transport function and urban setting. In most of the guides, however, the main focus is on the needs of through traffic.

There are great differences in how environmental friendly modes are treated in the main street guidelines in different countries. According to Civitas’ survey, the design advice and guidelines published in Germany and the Netherlands stand clearly out as having the most comprehensive descriptions of the various considerations that need to be made when one wants to balance the needs of transport and urban place, and to support the development of more environment friendly transport.

Our conclusion is that Marshall’s problem identification is too far out on the pessimistic side when he refers to current road and traffic planning practice, at least in most European countries.

Marshall notes (p.29) that highway design guidelines only deal with components of the road network, i.e. the design of links, junctions and their relationships, but that they do not prescribe the resulting overall pattern. As he partially recognizes, this is an advantage and a flexible opportunity for creative urban planning, which planners have been using for many years already.

Marshall deals very briefly (p. 36-38) with the ongoing debate about preferred and discouraged patterns of street networks. He refers to Brindle’s (1995) warning of seduction (!) by the neo-traditional call for grid networks, but does not follow this up with any special discussion or analysis. As mentioned earlier, he also draws the conclusion from his

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⁶ Australia, Belgium, Canada, Denmark, Finland, France, Germany, Hungary, Japan, Netherlands, Norway, Scotland, South Africa, Switzerland, USA.
analysis that the open grid network should not automatically be seen as the key answer to more urban solutions. Neither does his suggestion of a constitutional archetype give any clear and practical answer to the question of what type of network should be preferred.

**Insufficient treatment of other modes than the car – despite the idea of a transit-oriented network hierarchy**

Marshall’s interesting exposé of the nature of network structure, ironically much from the car user’s perspective (through the conventions of route definition that he recommends), means that it takes some 180 pages before he comes to the obvious conclusion that the network structure that is well suited for the car user, is different from the requirements of public transport and pedestrians.

Then he makes (in chapter 8) a brief analysis of other modes than the car, and he comes up with the very good idea of the transit-oriented and speed classified network hierarchy.

If he had started from there with an analysis of public transport, pedestrian and cycling networks (which are much more difficult to find on maps!), it is likely that some of his conclusions would be rather different, and more useful for future urban network development.

When Marshall seems to take the street-based network solution as the clearly best solution in today’s car-based society, he ignores the very real conflicts of interest and function between car users, pedestrians, cyclists and public transport passengers and operators in the traditional urban street open for all users, including the car user with or without an origin or destination in the street in question.

One approach to such discussions would be the analysis of the capacity and space-efficiency of different modes and network solutions. Another would be to study solutions and their capacity and urban and transport qualities in different types of streets and urban contexts.

Now all this looks as high priority topics for further work.

**Analysis of empty streets and cities?**

If we wanted to be ironic, we could say that Marshall’s study is an analysis of a possible and desirable network structure for streets and cities without people and traffic.

By not dealing with the challenges of transport demand, the problems of traffic flow and car parking, Marshall misses any possible understanding of the historical challenge and process of dealing with the rise of motorisation in the rich countries. The “conventional road hierarchy” is to a large extent explained as a modernistic negligence of the classical street-based urban form. The dilemmas of car accessibility and urban environment – at the core of the strongly criticized Buchanan report – goes without mentioning in a book intending to give advice on the structure of transport networks.

In chapter 8 Marshall concentrates on how modes and their speed affect the design of streets and roads. But what about traffic volumes and composition, and their effects on not only street design, but also how they and the buildings on the street will be used, their environmental qualities,
safety etc? And what about other criteria of network design, such as traffic safety, environmental concerns and efficiency of infrastructure and transport operations?

The negligence of car traffic nuisances and the importance of car traffic volume lead to a simplistic understanding of route arteriality, a key concept in Marshall’s network analysis. What is the value of an arterial to the car user if the route is congested, almost blocked, by car traffic?

Marshall’s focus on streets also means that he says virtually nothing about the upper parts of the classical road hierarchy, where speed and safety are of paramount importance for route design, and where also car traffic flow, capacity problems and environmental effects on the surroundings are major concerns.

**Insufficient treatment of urban place and design qualities**

Even more surprising to us, also Marshall’s treatment of urban place and design qualities has significant gaps that must be covered before proper guidance on the topic of network structure and design can be presented.

First, we note that Marshall proposes (chapter 8, p. 211) an urban space classification of highly subjective nature. We doubt that an ordinal ranking of the urban space in relation to geographical scale of importance will be very helpful. To us, Marshall’s idea seems very academic. More sophisticated forms of analysis of urban space, cultural and historical qualities, activities and use, will be needed in practice. Nevertheless, how this idea could be used in practical planning is illustrated in the ARTISTS project (Svensson et al. 2004) on arterial streets, where Marshall has been a key advisor. We return to that project later in our paper.

Secondly, Marshall’s final proposal for a street-based constitutional code (table 9.1) refers to the important aspects of land use and urban design. But in his book these aspects are “thrown in” at the last stage of analysis, more as a quick reminder to the reader than an integrated part of the analysis.

It is easy to see that the urban land use, place and design aspects of network structure and design will require a separate and much more extensive analysis. This is the other significant “hole” in Marshall’s analysis, in addition to the unmentioned topic of traffic volume and flow that reflects the use of the urban structure by people and their activities.

Presumably Marshall will deal with the connections to urban design and town planning much more in depth in his announced, forthcoming book titled “Cities Design and Evolution” (chapter 10, note 3). We are eager to see how far the new analysis will take us.

**A long way from theory to practice**

Marshall’s “constitutional archetype” framework for urban network development is an open-ended framework where the main intention seems to be to secure and strengthen the future role of traditional streets.

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7 ARTISTS = Arterial streets towards sustainability
Marshall ends up (p.218) arguing for a mosaic of street solutions unlimited in the numbers of types and variations, only structured and restricted by the parameters of speed bands and transit-oriented arteriality.

But: What will happen if future urban network design work is based on codes that give them the enormous freedom of choice that Marshall claims for his proposed system of constitutional code? How should the planner of a transport or urban development project, or the city planner, choose between the multitude of options that his approach opens up to? Who should decide, and how can one safeguard consistent results over time?

Will all these different classifications and theoretical analyses be of much help in the practical planning process? We have some doubt.

**Why not use a classical empirical planning approach?**

This leads us to our last counter-question. Why not find more directly out what constitutes well functioning streets and transport solutions in different contexts? Why not evaluate existing “best practice”, and find out under which criteria and circumstances certain types of solutions are “good” or “bad”, and then tell everybody about the results?

In a practical planning situation: What about doing what urban traffic planners have been doing for a long time when creating coordinated plans for all traffic modes, street and road use:

- Define each user group’s requirements and design the network each of these users need (e.g. pedestrians of different categories, two or three groups of cyclists, public transport and car users with or without origin and/or destination in the study area, etc.).
- Study all other qualities and requirements of urban place and street uses, and the safety and environmental qualities that are wanted.
- Then combine the desirable networks of different users with urban place qualities, safety and environment requirements to create one or several preferred solutions.

The evaluation of the different qualities and impacts of the scheme will then let the political system make an informed and balanced decision.

This approach is in line with the TRAST advice about the planning process, and is also supported by several of the commentators in the debate in Sweden. The planning and design process recommended in the ARTISTS project is also in the same tradition.

**Some points for further analysis**

Our conclusion is that Marshall’s classification of routes according to speed and transit-oriented arteriality is a useful and innovative contribution to network design. This idea should be further developed by looking into more detailed aspects of how to design the network elements of this type of structure. One important input could come from the analysis of best practice in public transport network planning, such as documented by Civitas et al (HiTrans 2005).
In our opinion, Marshall’s approach must be supplemented with considerations of traffic safety and a broad set of environmental factors. The importance of these factors in relation to both the traffic circulation and urban place qualities must be incorporated into the analysis, and also the costs of building and maintaining the infrastructure must be considered. Factors affecting urban liveability, use of urban open space, street life and economic activity, shopping, etc. should be incorporated.

We must look, not only at the structure of the empty streets and city, but also at the implications of people and their activities, circulation and traffic flow using the structure of the urban networks and built environment. Arteriality of a network, car-oriented or transit-oriented, is of little use if it is blocked by a heavy flow of congested traffic.

For practical application in the context of giving advice on urban network design Marshall’s idea of simple ranking of urban place qualities will definitely need more detail about the basis of evaluation.

3.3 The alternatives promoted in the “TRAST debate”

We now look at the proposals that have been presented in the Swedish debate about alternatives to the principles of segregation and differentiation of traffic in urban areas. We try to sort out the main principles that have been recommended by various participants in the debate, look at the comments they have inspired, and add our evaluation of the same ideas.

Diffuse relationship between goals and proposed means

First, we look at the recommendations that Hagson (1999) has come up with as an alternative to the conventional principles of Buchanan, SCAF and others. The basis for his advice is presented in a separate working report (Hagson 2000). We have earlier (Nielsen 2002a and 2002b) commented on his work in a paper presented to the Swedish Roads Administration, who also sponsored Hagson’s work. We will summarize our main points.

Of course, recommendations on the design of traffic systems and transport policy can only be understood in relation to specific problems to be solved. According to Hagson (1999, p. 12), the following problems have been difficult to solve because of the conventional approaches and principles of urban transport design:

- To stabilize and, in the long term, reduce emissions of carbon monoxide.
- To reduce the number of traffic deaths and serious injuries significantly towards nil in the long term.
- To reduce traffic noise annoyance both indoors and outdoors.
- To improve accessibility for the carless, especially for the elderly, children and handicapped persons.
- To create attractive, safe and secure urban environments, and protect the cultural heritage.

As a summary of his work, Hagson presents ten recommendations for an alternative approach (Hagson 1999). However, he provides very little theoretical or empirical evidence that might convince a reader that his
proposals and recommendations will be more successful in meeting these challenges than the principles he discards. A quick look at his recommendations will show this.

**Dense urban development – but do not expect too much from mixed land use in terms of reduced travel**

His first two recommendations deal with distance:

1. Concentrate urban development, mix urban functions and build and reconstruct the city with a grid network and closed blocks of buildings.

2. Use the traffic system as an instrument to change city structure in this direction, by the development of a grid network and with great freedom for the location of different functions, without attempts to control the location of disturbing functions.

These two ideas are quite usual in the urbanistic critique of modernistic urban planning, and it should be common sense that the average distance between a given number of inhabitants, work places and services will be shorter at high density than at low density. However, it is not so evident how people and businesses will adapt their activities and transport behaviour to the more concentrated and mixed land use situation, and Hagson does not provide any empirical evidence whatsoever to support his argument.

But other research (not mentioned by Hagson) on travel behaviour in different urban situations give support to the idea of the concentrated city as a means to reduce total car travel and increase the market share of more environment friendly transport modes. On the other hand, the idea that a local balance between homes and workplaces in a town or a smaller part of an urban region will reduce the distances of journeys to work has been refuted by studies of travel patterns. We will look into the evidence on how land use planning may affect travel behaviour in chapter 4.

**Traffic integration and slow speed - but all streets are not equal**

Like other critics of the traffic differentiation and segregation principles, Hagson (1999) recommends the mixed use street as the ideal urban traffic solution, with low speed as the basic requirement. To support this principle of integration he launches five recommendations:

3. Do not divide the city into 30 km/h-zones and do not distinguish between main streets and local streets.

4. Do not use travel speed by car as a measure of the quality of the street network.

5. Do not use existing advice about the geometric design of streets.

6. Do not use the design advice for 30/30-streets given in the design guides “Lugna gatan!” (=“Calm the street!”) and “Säkrare trafikmiljö i tätort” (=“Safer environment in urban traffic”).

7. Reduce the amount of car traffic by slowing down the speed of traffic.

Hagson does not offer much factual evidence to support these recommendations. However, in the next chapter we will look at some of the evidence available, and the conclusion is that there is much support in
the research literature for the idea of slowing down car traffic speeds in urban areas.

Since the 1970’s the idea of reducing car traffic speeds in urban traffic has been gaining support all over the western world. The key technique is to redesign streets so that they encourage, and even force, car drivers to reduce their speed, and to give more space and crossing time to pedestrians, cyclists and other street users. To-day “traffic calming” has become a key phrase in urban traffic planning, also in the car-based cities of USA and Australia.

Now speed reduction and urban place improvement on all types of urban roads has become mainstream traffic engineering, so it is easy to agree with Hagson that enforcement of slow speeds should be a key element in a policy for more sustainable urban transport. Not only because of the improved urban environment and safety that is directly achieved, but also because this makes the environment friendly more competitive against the motor car in the travel market.

We also agree with Hagson (1999, p. 24) that the need for speed reduction and environmental improvements is most urgent along arterial main streets. These streets have the greatest concentration of traffic related environment problems: High accident risks, in particular for pedestrians and cyclists, the greatest concentration of urban street activities, often major public transport routes with significant delays due to car traffic congestion, noise and air pollution where the concentration of street user’s is at its greatest, etc.

However, we do not understand the reasoning behind the idea of not differentiating measures and traffic speeds between different routes and streets in the city, as indicated by the first recommendation above. In order to achieve the aim of a more sustainable and livable city, the traffic system must be adapted to the mixed, inhomogeneous structure of the city. Urban activities, transport demand and the sensitivity to traffic disturbance and risk vary hugely between different areas and streets in an urban area.

As we later will see, significant environmental benefits can be gained by directing heavy car traffic to main routes where there are fewer pedestrians and cyclists and less conflict with urban place functions, residential buildings, etc.

**Improve the networks of environment friendly modes**

Hagson’s (1999) three last recommendations are:

8. Increase the modal share of walking and cycling through continuous networks, priority measures at junctions and crossings and measures to discourage short car journeys.

9. Guarantee the quality of street environment at the detailed planning stage.

10. Clarify the role of public transport, develop its competitive ability against the car on specific relations and consider the consequences for public transport of all changes in land use.
Although Hagson does not offer any substantial evidence of the effects of these measures, the recommendations are in good tune with common policies for more sustainable transport. His recommendation (Hagson 1999, p.31) of a pedestrian and cycle network as segregated as possible from car traffic – in addition to mixed traffic streets – is also in good harmony with international advice on planning for walking and cycling. However, by this he contradicts an important point of his critique of the SCAFT principles, where he argues against Radburn type residential areas with separate pedestrian and cycle routes that are little used.

The inconsistency of Hagson’s analysis also comes out in his call for measures to discourage short car journeys. Very appropriately, he refers to the fact that distances between many destinations in Swedish urban areas are generally rather short. Many car journeys could be substituted by cycling or even walking, and he recommends a stick and carrot policy to induce car users to change mode.

One of the most effective ways of doing this is to restrict the local car network through the creation of environment areas, where the routes for buses, cyclists and pedestrians become shorter than those of cars. One of the ideas of the environment area, and the neighbourhood unit, is to make it more convenient to leave the car parked for short journeys, and to give priority to environment friendly modes.

Hagson rightly refers to the inefficiency of the bus network in many conventional traffic networks based on the SCAFT principles. But, as we show later, these problems can be overcome without abandoning the benefits of the street and road closures of the environment area of the car traffic system.

Our conclusion is that Hagson (1999 and 2000) has made a number of very good points in his recommendations of principles for the planning and design of urban transport networks. But there are also some contradictions and inconsistencies in his argument, that require some sorting out.

As part of this process we continue our analysis of the critique and proposals presented by several other participants in the TRAST debate.

“Open” grid network or “closed” environmental areas?
A main topic of the discussion has been the question of the type of car traffic network that is most desirable:

– Should the principles of the environmental area be further developed? or
– Should the idea be abolished as a disurban idea from the car age, a sidetrack of thousands of years of urban tradition?
– Should the principle of the open grid network be the universal model for car traffic systems as well as for all other modes of transport?

Like us, Leonard Nilsson (no date), is sceptical of the universal applicability of the open grid network as the best solution for the car traffic network. He claims that this would only lead backwards, to a repetition of the traffic problems that existed before SCAFT was introduced. He suggests that planners should look more closely into the
interaction between the transport system and urban development. This analysis could then start with the question of how the transport structure affects development potential for different functions in different locations. And not only look at the connection from land use to traffic generation and solutions, as tends to be the case when the critics of the current transport solutions stress that they want a more neutral, “flexible” grid network that facilitates a more spontaneous mix of land uses and functions within the urban area.

Also Lars Nilsson (2001) has expressed doubts about the universal preference for the open grid network as the right solution for urban areas with high density and, because of this, large volumes of car traffic and parking demand. Like us, he is concerned about the environmental problems, especially in the older parts of the larger cities and towns just outside the city centre. These areas are under strong traffic pressure from the rest of the city, and are likely to suffer strongly if most of the streets were re-opened for car traffic. He too, has problems with envisaging that major city streets closed from through traffic by cars in the 1970’s and 1980’s should be opened up again for car traffic.

Remembering how inner city areas became protected from through traffic through popular resident’s action groups and responsive politicians in the 1970’s and 1980’s, we see the existence of these traffic solutions as a reasonable proof of the good sense.

Fällström (2002), on the other hand, calls for a full reconsideration of the area traffic management schemes that have been made in older street networks. He calls for a full restoration of the old grid networks for car traffic. He argues that the restricted car network has lost its functionality, and that an open and continuous grid network will create new location benefits sufficient to offset the possible advantages gained by the more restrictive traffic management schemes.

His argument is based on a reference to the so-called value-neutral architectural theory of Space Syntax analysis developed by Bill Hillier (et al) at the University of London8. It is claimed that:

- “Space Syntax has pioneered new, proven techniques for regenerating urban areas through urban design. These techniques focus specifically on making physical connections to integrate people and places. Their use in projects such as the redevelopment of BrindleyPlace in central Birmingham and Broadgate in the City of London has shown that the process of creating socially inclusive urban areas can be led by good urban design.

- Space Syntax is unique as a design tool because it allows factors such as 'connectivity', 'integration' and 'permeability' to be objectively measured. This allows the impact of design proposals to be forecast in advance, for example in terms of how these will affect existing patterns of pedestrian movement, space use, economic vitality and safety.”

We have not had time and resources to verify these claims for the Space Syntax methodology, but are basically sceptical to the novelty of this

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8 According to Fällström, this type of work is represented in Sweden by Lars Marcus at KTH
approach and its unique ability to forecast people’s behaviour in a complex social, urban situation.

Fällström’s plea for a stronger regional planning authority in order to develop more rational urban structures than the planning monopoly of local authorities can deliver, is easier to understand and support. Furthermore, Fällström (2002) supports strongly the idea of the mixed land use or integrated city of relatively high density. With reference to research literature by Gunilla Belander at CTH, Gothenburg and Peter Næss at NIBR, Oslo and AUC, Aalborg, he claims that this type of urban structure will be more transport efficient and also more flexible and competitive as a business location than the functionalist, segregated city that he claims have dominated much of urban development in Sweden after the second world war.

Alternatives to conventional development – illustrative examples for Södermanland

In order to better understand the arguments of the new urbanists, we have studied an “inspiration book” which has been made to stimulate popular debate about urban planning and development in the county of Södermanlands län in Sweden (Södermanlands län 2004).

The book does not specifically address all aspects of the principles of urban development and road transport network design. But it presents a number of illustrations of possible types of development in various towns and villages in the county. We take these as illustrations that might help us as to understand more fully the critique of the conventional approach, and the alternative that is being advocated.

The basic principle of the ideas for urban development in Sörmland is to improve existing settlements by giving them more urban qualities and to concentrate development along roads and corridors well suited for improved public transport services, by bus or rail.

To be honest, this is an old idea. This type of sensible, regional development model has been very common in urban and regional planning for many years. But the illustrations on how this might be achieved in the context of the county of Sörmland are enlightening.

We first note that three international examples are used for inspiration (without going into details of urban design and network structure):

- The American new urbanism’s demonstration town of Seaside, Florida
- The model town of Poundbury initiated by Prince Charles in England
- The recreational town of Port Grimeau on the French Riviera.

This confirms the ideological connections between the New Urbanist movement in the USA and the Swedish debate. This is even more clearly shown by one of the illustrations of the model of urban development by Arken architects (p.23). It is interesting to observe that Arken’s illustration shows an open grid network inside the small town, but with indications of differentiation between streets, and probably also a car-free large square at the centre. The town is also connected to a hierarchical, regional road and transport system.
The model example (p. 74-75) of the small seaside town of Port Grimeau, with some 2500 houses on a large number of small, artificial islands, is also interesting for its transport solution: Most of the small town, which contains some 2000 permanent residents and some 20000 summer vacationers, is car-free. Cars are only allowed access for deliveries, walking is the main mode of movement inside the town. Although there are bridges that connect many of the islands, the street structure of the town consists of many cul-de-sacs.

From this we can conclude that at least some new urbanists can accept:

- A hierarchical structure of the main transport network
- Fairly large car-free urban zones
- An access road structure with blind ends or cul-de-sacs.

In other examples of existing patterns of development in Sörmland, the book makes critical comments concerning two aspects of urban form:

- Single-function housing estates are isolated from the rest of the community by large stretches of open land.
- The road layout of these estates, with cul-de-sacs and closed circuits to make them safe without through traffic by cars, isolate houses from the surrounding area.

Examples in the towns of Trosa and Nyköping (p. 46) are highlighted and contrasted negatively with the older, traditional continuously built-up area with open-ended streets.
It is claimed that the traditional street pattern stimulate more street life and that more spontaneous meetings may take place because of through traffic and passers-by that might find something new and unexpected on their way. With the closed street pattern, and single function land-use, of the housing estates of the modernistic planning, only people or traffic with a pre-defined purpose of going to a particular address will be found on roads or streets of the estate. Hence the argument that open ended streets stimulate social life and urban creativity.

The proposals for infill and further development of some of the towns and settlements of Sörmland illustrate the type of street networks and urban form that is advocated.

At Storängen, an existing industrial area in Strängnes, a new bypass highway is proposed (p.28) for E 20 and the exhibiting industrial though road is proposed transformed to “Storängen Boulevard”, reduced from four to two through-running car lanes, with new buildings on both sides, pedestrian sidewalks, an alley of trees and improvements for cyclists and public transport by bus. Similar “urbanisation” is also proposed for other roads in the area, changing the place character to that of small town streets, from something more like an industrial estate. A new mix of housing, business and services is envisaged, while the existing location of one of the heavy industrial functions (concrete element production) is suggested moved out in order to improve the area.

In the industrial town of Oxelösund a similar approach of redesigning the car-oriented road system is advocated. Rerouting of heavy and non-local traffic is suggested (p.78) onto a planned new bypass, Östersjöleden. However, it is suggested that the downscaling of the town’s car road system could be done without much problems for car traffic, so it would not be necessary to wait ten or twenty years for the money to build the bypass. The proposal suggests new buildings along both sides of the existing main road, and a Ponte Vecchio (Florence) development on the wide main road bridge.
These examples show that the plans for some of the towns are advocating a form of car traffic redirection, which in practice many will see as dependent on a new section of high standard main road, and also land use changes which will relieve the area of some heavy goods traffic.

No information is given about the volume and composition of motor traffic that is considered acceptable for the type of streets one wants to have. Neither are the proposals for by-passes and traffic re-routing accompanied by any analyses of transport demand and geographical patterns. However, this is a reflection of the book’s intention to inspire debate and alternative thinking, not to complete the analysis.

Among the development “rules” that are suggested for the largest town of the county, Eskilstuna (p. 36), a lot of rather drastic regulations are proposed:

- Big open parking lots, motorways and high speed driving should be prohibited.
- All properties in the town should be small, and nobody should be allowed to own more than one block.
- Many more houses should be built along existing roads to create proper urban streets with mixed uses and active street life.
- Different land uses should be mixed and new urban places should be created.
- At street level all buildings should have active and open functions that contribute to the vitality of the streets.

Concerning the road network of this old industrial town, traffic calming and “urbanisation” of traffic architecture is advocated. Car traffic should be distributed “thinly” through the street network, not concentrated to a few more heavily trafficked routes.

Again: No figures are given to indicate what is meant by “thin” and “heavy” motor traffic. However, more direct routes for walking, cycling and bus travel are suggested. A proposal for new bridges over the river is part of this concept. Together with increased density of land use they will, it is claimed, contribute to a reduction in short car trips in the town.

The planners also call for a more open discussion of the trade-off between traffic noise protection through barriers and distance and the urban qualities of the street with car traffic much closer to the houses.

For Nyköping (p. 48) the same type of road urbanisation is envisaged: The existing harbour road is proposed transformed to an “esplanade” with existing closed side roads opened up with several new junctions formed as traditional street corners. This will, it is argued, reduce driving speed. A free standing housing estate is suggested connected to the rest of the town by a new seaside street with a belt of new urban development. This, it is argued, will make the distance between the old estate and the town centre more attractive for walking and cycling.

Problems of the new street attracting unwanted through traffic, accidents, noise and pollution, should be counter-attacked by slow design speed and traffic calming measures, combined with the routing of car traffic to the
main road system where industry and warehouses can be used as protection barriers.

Also in the town of Katrineholm, a new bridge and a new railway underpass is envisaged in order to shorten routes for pedestrians, cyclists and public transport. These are seen as expensive infrastructure projects, but they change the competition between modes towards more sustainable transport, and are seen as manifestations of a new type of urban development away from car dependency.

We can conclude that much of the principles of the relatively antagonistic theoretical debate about network design are less rigidly applied as soon as it comes to practical applications. If the illustrations of Södermanland can be taken as typical, we see that a mixture of old and new design principles are applied. The challenge is to try to find some clear evidence of when or where the different solutions might be appropriate.

**Towards a two-tier car network strategy?**

Lagerquist’s (2000) suggestions for a more attractive and sustainable city are similar to many other books and planning reports on the topic, and several of the points have been mentioned above. However, we take special note of the recommendations that are particularly relevant to our discussion of network principles:

The urban street is the basis for city life. Therefore motor traffic should be reduced to levels tolerable for street activities and urban life, and the streets should be designed to cater for and stimulate the urban activities and functions.

The traffic and urban place roles of all streets should be evaluated and all streets and roads in the city should be classified according to their environmental capacity. The environmental capacity of the “weakest” link should determine the role of the continuous traffic routes through the whole city.

Traffic space should be minimised in order to keep maintenance costs low, and the modal split of transport in the city should be adjusted to the environmental capacity and space available. A series of transport policy measures should be introduced to achieve the modal split required.

A car traffic network with only two-tiers is recommended:

- Main traffic distributors, with speed limits of 70-90 km/h, some 5-8 km between the routes, and both single and multi-level junctions.
- The urban street network, a dense network of streets adjusted to their urban and traffic functions and speed limits of 30-50 km/h.

The continuity of the street and road network should be strengthened, and the degree of differentiation and separation between traffic functions should be reduced, but not entirely abandoned.

Lagerquist also recommends simple and logical traffic design with standardised junctions along main traffic routes and clear information design, signing and naming of streets to ease orientation.
Lars Nilsson’s (2002) proposal of a “street room model” (“Gaturoms-modell”) makes a more clear differentiation between different types of streets. This idea has also been supported by Wramborg (2002), who describes this as a solution principle developed by the EU project Promising.

Five different classes of urban streets are described, which give different priorities to car traffic versus pedestrian and cycle traffic:

- Through traffic route (“Trafikled” in Swedish). Speed limit in urban areas between 50 and 90 km/h, with 70 km/h as the proposed, basic design speed. The purpose is (a) to offer fast and direct connections over longer distances by car, and (b) relieve sensitive urban areas of through traffic. According to Wramborg, new traffic routes have the negative effect of generating more car traffic.

- Main street (“Huvudgata”), with mixed traffic and 50 km/h as the normal speed limit, sometimes reduced to 30 km/h. Most of the bus network runs on these streets. Increasingly more junctions and important crossings for pedestrians and cyclists are designed for 30 km/h. Even lower speed limits may be applied on shorter stretches.

- Residential street (“Bostadsgata”) should have 30 km/h, and they have mainly local car traffic and some local bus services, in particular minibuses, service routes etc.

- Walking speed street (“Gågata” and “Gårdsgata”; Dutch “Woonerf, Norwegian “Gatetun”), where car traffic is allowed, provided the driver has appropriate concern for pedestrians, cyclists, children and local street activities.

- Car free area (“Bilfritt”)

<table>
<thead>
<tr>
<th>Type of street</th>
<th>Pedestrian access streets</th>
<th>Local streets</th>
<th>City streets</th>
<th>Car streets</th>
<th>Main traffic arteries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priority for pedestrians</td>
<td>100 %</td>
<td>75 %</td>
<td>50 %</td>
<td>25 %</td>
<td>0 %</td>
</tr>
<tr>
<td>Priority for cars</td>
<td>0 %</td>
<td>25 %</td>
<td>50 %</td>
<td>75 %</td>
<td>100 %</td>
</tr>
</tbody>
</table>

Figure 26. The urban environment according to the street room model: (a) Free room without cars (b) Soft traffic room with a mix of motorised transport and urban place functions (c) Transport room. Four types of street, and one class of arterial, main road with different priority between car traffic considerations and the requirements of pedestrians and cyclists (Nilsson 2002).

Nilsson argues that this model would give balanced solutions, with due consideration of traffic safety for children and the elderly as advocated by
the Swedish Government vision of no serious injuries in the traffic (“Nollvisionen” and “Säkrare miljö i tätort (1997)”). Parallel ideas can be found in EU-projects and in the ideas of a more sustainable and city-friendly transport system in Sweden (“Lugna gatan”) and elsewhere (Traffic calming etc).

According to the proposal, the actual designation of the streets and roads in an urban region on the basis of this classification should be left to the urban and transport planning authorities of that region, in order to reflect local and regional political priorities and contextual conditions.

One comment must be made on the classification scheme presented in the figure: Public transport is not explicitly incorporated into the model, which we regard as a significant weakness of the idea.

Bjerkemo (no date) reflected on the fact that so much of the debate and classification discussions concentrate on the design of the car network, with very little discussion of the networks for other modes or of the environmental qualities of the residential areas.

He too suggests a simple two-tier approach to the design of the traffic network, distinguishing between the local network and the main network.

The local network should be an integrated network for all modes of road transport and provide access, short distances direct local connections, and offer a lot of good opportunities for street activities and interaction between all users of the city. Local traffic should be characterised by few large vehicles, slow speed, fine-masked connections, continuity and accessibility, and a high quality environment that is full of opportunities for interesting experiences, etc.

The main network (why not call it a transport network?) consists of specialised channels designed to serve important travel and transport needs, with capacities for heavy traffic flows and connections to national and international networks. The main network will have a large proportion of big vehicles and specialised modes of transport, higher speed but larger grid units than the local network. Considerations of the transport and travel environment are more important than the place qualities that have priority in the local network. The principles of network differentiation and traffic segregation are widely applicable in the main network.

In both networks the environment requirements should be paramount in controlling the choice of design solutions. When ideal objectives of environment quality are outside practical reach, Bjerkemo recommends the technique of “compensatory planning” – where one quality shortcoming is compensated by a different factor that is better than average.

The integration of the two networks, Bjerkemo suggests, could be assured by adopting the concept of “seamless mobility”. He also calls for the use of environmental indicators to define and measure the quality of solutions, both at the design phase and in the operational, long term stages. An integrated transport strategy, public participation and
partnerships between stakeholders are also necessary ingredients in the continued struggle for a more attractive and sustainable city.

3.4 Inconsistent proposals

**Diffuse connections between objectives and proposals**

Our overview and discussion of the debate on transport network principles and their effects show that there is an abundance of recommendations and proposals.

Taken together, the critique of present practice and the alternative principles promoted give a rather inconsistent picture. Some of the proposals are without scientific or empirical evidence of their likely effects on the environment, traffic patterns and urban activities. Some proposals even seem to be counter-productive in relation to the objectives the authors claim to have.

The rest of this paper tries to sort out some of the issues.

**Little new since 1978**

It is, however, interesting to note that the idea of an essentially two-tier road network was envisaged by the Nordkolt project of the Nordic Council of Ministers already in 1978 (Nordisk ministerråd 1978)⁹, see the recommendation on the next page. In fact, most of the principles that have been presented as “new” in the last few years of debate can be found in the discussions of traffic planning of the 1970’s.

**Many factors behind the lack of success in transport policy**

When making proposals of measures that efficiently could change the trends towards the almost totally car-based city, one should have a good understanding of the forces leading towards the large ”gap” between reality of the city and the political goals of reduced car transport and more sustainable cities.

The problem of mismatch between goals and results in urban transport policy during the last 30 years is certainly a challenge for policy makers. A study in the Norwegian research programme LOKTRA about local transport and land use policies summarized Norwegian experiences and concluded with five groups of factors that may explain the lack of success in relation to the stated political goals (Nielsen et al. 2000):

- The policy instruments that have been used are ineffective or counterproductive in relation to the goals.
- The organisational structure for dealing with the challenges of urban transport is inappropriate for the stated goals. Both organisation and the division of tasks form barriers against the implementation of an efficient policy.

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⁹ Gustav Nielsen was, together with the project leader Erik Sylvén, author of the report, which summarized results from a four-year study of Traffic in Nordic towns, with emphasis on the future development of public transport in medium-sized towns.
A road network for all users

Urban road networks do not always satisfy reasonable demands on safety, mobility and comfort for all groups of travellers. Coordination between the transport system and urban development is frequently unsatisfactory. Planning that includes the following principles is becoming more accepted:

- **Coordinated planning** of the traffic network and urban development to create a positive interaction between traffic and the town environment.
- **Comprehensive networks for all types of traffic**, easy to use and providing good mobility. Particular emphasis should be placed on the needs of pedestrians and cyclists for short, direct and convenient facilities in the best possible traffic environment, and the need for short walking distances to bus stops for public transport users.
- **Road network divided into arterials and local streets**, the former carrying through-traffic and the latter both local and other traffic.
- **Local areas (enclaves)** separated from the through traffic and, in older areas, created by traffic reorganization.
- **Separation in time and space** where there are serious conflicts between the different types of traffic. On the arterials this means separation of vehicular traffic and pedestrian, cycle and moped traffic (PCM traffic), and of bus and car traffic at locations where delays occur. Local streets within enclaves may generally be **mixed traffic streets** with car and PCM traffic. Separate bus streets can be provided through enclaves, for example, so as to allow centrally located bus stops and shorter route lengths.
- **Control by traffic signals** in locations that are dangerous and/or have a large number of conflicts, often with priority for PCM traffic and public transport. Linked signals, which improve mobility and reduce queue formation, should also give increased priority to PCM and public transport traffic.
- **Traffic speed** on a "human scale" with regard to the neighbourhood environment and the desire for safety and mobility for all users. This may mean reduced speeds for cars, particularly in mixed traffic streets. Physical design measures should influence drivers to maintain low speeds.
- **Traffic volumes** determined not only by the mobility requirements of all user groups but also with regard to adjacent development and the distinctive character of the neighbourhood environment. Control measures such as signals, parking restrictions, various types of charges, etc. can be used to regulate the amount of traffic.
- **Simplified and standardized traffic environment**, mainly within the arterial network, so that users have clear and direct information on the road's function, permitted or recommended speeds, and suitable routes. Superfluous "information" should be minimized.

Figure 27. Copy of the Nordkolt project’s summary of recommendations for the design of the road network (Nordic Council of Ministers 1978:16e).

- Planning and development processes are dysfunctional in relation to the goal of reducing the car share of the urban transport market. The
professional paradigms of the car and road building interests have been too
dominant.

- The distribution of resources in the form of professional expertise, time and
money has been biased.

- Too weak after-control and evaluation of policy measures and proposed
solutions that have been put into practice; with too little professional and
political learning taking place.

These conclusions are consistent with results from several international
studies of success factors in urban transport policy with ”success” being
defined as the achievement of political goals concerning modal split,
public transport, economic efficiency and more sustainable cities and
urban regions.

Nielsen et al. (2005, chapter 2.3) summarized key factors of success in
urban transport policy based on comparative studies of transport policy in
predominantly European cities. Empirical evidence suggests that good
practice seems to have four interrelated factors in common. These are:

- Regional organisation: The existence of some kind of regional structure is
the element that many authors have argued as essential.

- Funding: A willingness to commit funds to both operations and
infrastructure by relevant stakeholders is a pre-requisite and by itself would
appear to be able to generate public transport patronage, but not modal shift
from car.

- Supporting policy: Complementary policies that reinforce the underlying
transport policies in their achievement of modal shift.

- Land use and transport co-ordination: Successful co-ordination between
land-use policies and transport policies in recognition of their conjoint
spatial attributes.

It is also clear that urban transport policy success depends on the
combination of a large number of measures, and that push and pull
strategies must work together.

Although the design of the transport network is an important factor in the
process of traffic growth and expanding car use and other changes in
travel demand, one cannot put all the blame for the problems of the car
society on this single urban design element.

We feel that some of the critique of conventional traffic planning and
design is exaggerated. From this, it follows that the expected effects of
the alternative proposals and recommendations are sometimes too
optimistic.

The purpose of the next and final chapter of analysis is to look closer at
some of the relationships between car traffic, network design and the
urban environment.
4 Infrastructure, environmental capacity and effects of traffic

4.1 Urban environmental criteria – defining the objectives

A main reason for the rather confused professional debate on the principles of urban network design is the lack of definitions of the objectives to be reached. As long as we are without clear and consistent descriptions of what we are trying to achieve through the planning and development of the urban road network, we cannot distinguish between good and bad practice. Neither can we conclude the debate about the principles of traffic segregation or integration.

The critique of traditional road traffic design – and the TRAST project for new planning and design advice on the urban transport system – stems largely from a desire to develop more environment friendly cities and urban transport solutions.

Responding to the critique of the traditional road planning approach it is useful to take two steps forward in the analysis:

- First, urban transport and road link functions must be seen in relation to the type of urban functions and places that is being served by transport.
- Second, environment quality criteria must be defined for the different types of urban functions and types of area in the city.

In order to create a basis for the evaluation of the principles of road network design we refer to two recent attempts to define the urban environment qualities we are seeking for.

First step: Take account of urban place functions

The EU project ARTISTS (Arterial Streets Towards Sustainability; Svensson (ed) 2004) was developed with the aim to find better guidance for designing urban streets that serves several functions. As opposed to arterial roads, serving primarily through traffic, and access streets, designed with focus on the local user, the project defined the arterial streets, which combine significant through traffic and urban place functions. The ARTISTS project discusses the need to come up with better methods to define and analyse the functionality of arterial streets.

The project argues that the arterial street has always existed as a natural part of cities. They were often originally radial routes that were caught up by the growth of the city and gradually became part of the urban place. The arterial street combines the transportation role with the role as an environmental and social setting for people, stores and activities. As traffic grew in the late 20th century, the arterial streets were considered dysfunctional, and planners increasingly developed strategies to separate streets with high traffic volumes (arterial roads) from streets with a local focus (access streets).

The same analogy can be used for smaller cities and community centres. As with any larger city, the smaller places originated because they were located in the junction were two or more roads or railroads met. As traffic increased the junctions took hold of these places and through traffic
became defining for their identity more than the qualities of the place as a destination itself.

**Link and urban place status**

The ARTISTS report argues that the term sustainability must be given a holistic perspective, as streets form part of a complementary system, and cannot be analysed as separate parts. The objective is to come up with a system that “encourages the appropriate mix and levels of social and economic activity for an area, while minimising environmental damage”.

The project suggests a simple classification system that takes into account the relative significance of any particular street both as a link and as a place.

![Classification System Diagram](image-url)

Figure 28. ARTISTS’ classification of link and place status (Svensson (ed) 2004).
The street’s *link status* defines the relative significance of a street as a link in the network. It will typically describe to which degree this is an arterial, or an access street and how important its function is to the whole network.

The *place status* of a street section relates to the streets significance as an urban place. As with link status, the classification is defined in relative terms with respect to the surrounding geographical area. A street may have local importance as a place, or cater to a wider region in terms of attraction and use.

**ARTISTS’ sustainability indicators should be improved upon**

In the process of developing a strategy for the design of the urban street and transport network, the ARTISTS’ first step of recognising the importance of the urban place functions is strongly needed. This will clearly meet some of the critique of traditional road hierarchical road network planning.

However, in our view, the projects’ suggestions for how the urban status should be defined and the implications for the final design of streets, are rather inadequate, and should be improved upon.

Following the classification of link and place status, the ARTISTS report suggests developing indicators to measure social, economic and environmental sustainability. Figure 29 shows the ARTISTS’ sketch of an analytical system for measuring sustainability indicators for street and place functions. While the matrix is elegant in its simplicity it also illustrates the problem of finding indicators that are suitable for comparing alternative strategies that affect a larger area, and for weighing link status against place status.

![Figure 29](https://www.svensson.com/fig29.png)

**Figure 29. ARTISTS’ sustainability criteria for street performance in relation to link and place functions (Svensson (ed) 2004).**

<table>
<thead>
<tr>
<th>Link function</th>
<th>Indicator</th>
<th>Place function</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Social sustainability</strong></td>
<td></td>
<td><strong>Economic sustainability</strong></td>
<td></td>
</tr>
<tr>
<td>Safety of vehicle occupants</td>
<td>Safety of pedestrians</td>
<td>Movement efficiency along the link</td>
<td>Viability of the place</td>
</tr>
<tr>
<td></td>
<td>Car accidents</td>
<td>The ration of the flow of people to ADT</td>
<td>Rents and sales</td>
</tr>
<tr>
<td>Safety of pedestrians</td>
<td>Pedestrian accidents</td>
<td>Delay of vehicles and pedestrians along the link</td>
<td>Delay of vehicles and pedestrians across the link</td>
</tr>
<tr>
<td>Vehicle speed</td>
<td>85 % speed level</td>
<td>Delay across the link</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Environmental sustainability</strong></td>
<td></td>
<td><strong>Environmental sustainability</strong></td>
<td></td>
</tr>
<tr>
<td>Air quality inside vehicles</td>
<td>Concentration of pollutants</td>
<td>Air quality on sidewalk</td>
<td>Concentration of relevant pollutants</td>
</tr>
<tr>
<td></td>
<td>Noise level</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Greenery</td>
<td></td>
<td>Indication of greenery</td>
</tr>
</tbody>
</table>
For example, what are the comparable alternatives for evaluating car and pedestrian accidents? A traffic calming strategy might improve safety along one specific link given no change in traffic volumes. However, moving motorized volumes from that link to another one might result in even larger improvements, both for the specific link and in a broader perspective.

Another challenge is how to evaluate delay across a link against delay along the link, and how to compare viability indicators with efficiency indicators without studying a larger geographical area. The ARTISTS project is founded on the notion that arterial streets are a necessity in modern cities, but that the street’s status as a place, rather than just a link, must be emphasized in order develop better design principles.

However, when it comes down to the definition of place status, the project chooses a rather simplistic analogy to the traditional, hierarchical classification of road links: ‘The place status is, like the link status, related to the geographical scale with regard to frequency and type of use, and in principle relates upwards (from local) to national or international scale significance.’

Some examples of the possible basis for the designation of status of places are given: Commercial streets and spaces may be classified according to their national, regional or local roles and catchment areas. Civic streets and spaces may be classified similarly according to their civic role or significance, and the same type of hierarchical designation may be made for recreational streets, spaces and parks.

By this, ARTISTS offers the same type of status classification for link and place functions, which looks nice in theory. The project even claims that ‘This puts link status and place status intrinsically on an equal footing, therefore allowing a real sense of balance between ‘right of way’ versus ‘right of place’’ (Svensson (ed) 2004, page 28).

We object to this approach to the definition of urban space requirements for the design and traffic solutions of streets. This hierarchical approach does not say anything about the type of environmental criteria used to
establish what is meant by ‘balance’ between link and place functions. A regional place status will not necessarily be equal to or balanced with a regional link status, and neither will this status say much about the environmental qualities to expect in a street or urban place of this class.

Sustainability indicators have traditionally been developed for analysis on the link functions, and there is a need to develop better indicators for the place functions. More importantly, there is a need, in each study, to define the area of interest to such an extent that all relevant relationships are being evaluated.

Ideally, the tool that is sketched above should be developed for a holistic perspective so as to facilitate the definition of which roads and streets can take more traffic than others. However, once at the strategic level of planning, there are many other questions that needs to be asked, and land use and transportation strategies must be studied with the appropriate models and tools, taking into account travel demand and modal split and the tools to affect them in the longer perspective.

Second step: Define the environmental criteria for different types of streets and urban functions

We do not have the resources to create a complete and consistent alternative approach to the ARTISTS’ classification of urban place status and their environmental quality criteria. However, one possible approach can be proposed.

In a recent study for the planning and transport authorities in the Oslo region (Nielsen et al. 2006), a set of 17 different criteria for the definition of urban environmental quality was proposed. The proposal was made on the basis of existing political goals for the city and its transport system, and research literature on the environmental effects of urban road traffic. It also included factors that, according to the urban design professions, should be considered in good practice in the practical design and renewal of urban streets.

For each of the 17 different environmental factors, the study suggested how three levels of environmental quality might be defined. The idea is to achieve some sort of common understanding about what constitutes environment friendly solutions, or at least a basis for more systematic analyses and discussions.

The highest environmental quality level was defined so as to satisfy urban health criteria, the well-being of citizens and to stimulate urban street life. It was defined, not as a utopia, but so as to reflect what has been shown to be achievable in practice in certain areas and streets of modern European cities.

The low environment quality levels are to a large extent situations that have a politically declared goal to be improved (e.g. the average existing levels of traffic safety in the City of Oslo), or some formal requirement of abatement measures (e.g. noise or air quality regulations).

The following table describes the 17 urban environment criteria and the three different quality levels. It should be seen as a first attempt to define a broad-based cheque list for the urban environment in relation to traffic.
Figure 31. Proposals for a cheque list for the definition of three different levels of urban environment quality (Nielsen et al. 2006).

<table>
<thead>
<tr>
<th>Urban environment factor</th>
<th>Level of environment quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspects of evaluation</td>
<td>Low</td>
</tr>
<tr>
<td>1. Living city</td>
<td>Low quality urban life</td>
</tr>
<tr>
<td>Volume and intensity of</td>
<td>Few people walking or staying</td>
</tr>
<tr>
<td>the use of public space</td>
<td>in the area; most visits are for necessary purposes.</td>
</tr>
<tr>
<td>Building functions and</td>
<td>None or few people-attracting</td>
</tr>
<tr>
<td>their interaction with</td>
<td>activities. Long, “dead”</td>
</tr>
<tr>
<td>the space between</td>
<td>facades towards the public</td>
</tr>
<tr>
<td>buildings</td>
<td>spaces.</td>
</tr>
<tr>
<td>Space for staying in</td>
<td>Small areas, too unattractive</td>
</tr>
<tr>
<td>public spaces</td>
<td>for staying in the public</td>
</tr>
<tr>
<td>Car traffic environment</td>
<td>Heavy traffic with fumes</td>
</tr>
<tr>
<td>disturbance</td>
<td>and noise masking normal</td>
</tr>
<tr>
<td>Quality of experience</td>
<td>Unattractive environment</td>
</tr>
<tr>
<td>2. Walkability</td>
<td>Low pedestrian quality</td>
</tr>
<tr>
<td>Pedestrian routes</td>
<td>Links with no provisions</td>
</tr>
<tr>
<td>Free width of walking</td>
<td>Narrower than required by</td>
</tr>
<tr>
<td>area</td>
<td>the City of Oslo road</td>
</tr>
<tr>
<td>Crossings of car traffic</td>
<td>Level crossings of heavy</td>
</tr>
<tr>
<td>Quality of experience for</td>
<td>Significant congestion and</td>
</tr>
<tr>
<td>walking</td>
<td>wide spread barriers and/or</td>
</tr>
<tr>
<td></td>
<td>depressing, uninspiring</td>
</tr>
<tr>
<td></td>
<td>environments make walking</td>
</tr>
<tr>
<td></td>
<td>an unattractive experience.</td>
</tr>
<tr>
<td></td>
<td>Much noise and pollution</td>
</tr>
<tr>
<td></td>
<td>from car traffic.</td>
</tr>
<tr>
<td>Urban environment factor</td>
<td>Level of environment quality</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td><strong>Aspects of evaluation</strong></td>
<td><strong>Low</strong></td>
</tr>
<tr>
<td><strong>3. Universal accessibility</strong></td>
<td>Not accessible</td>
</tr>
<tr>
<td>Access</td>
<td>Many barriers, such as high kerbs, water drains?, rough cobbled surfaces, loose gravel, etc.</td>
</tr>
<tr>
<td>Orientation and information</td>
<td>No special markings or signs for pedestrians, users of wheel chairs, etc.</td>
</tr>
<tr>
<td>Other qualities</td>
<td>Loose signs and random parking of bicycles, cars etc. in pedestrian routes. Few provisions at building and road repair sites. Unsatisfactory noise and air quality.</td>
</tr>
<tr>
<td><strong>4. Traffic safety</strong></td>
<td>Low level of traffic safety</td>
</tr>
<tr>
<td>Traffic accident and injury risk at the urban district level.</td>
<td>As the average for the City of Oslo in 2004.</td>
</tr>
<tr>
<td>Injury accidents per year and 10 000 inhab. + work places.</td>
<td>13 (Inner city 2004 = 12)</td>
</tr>
<tr>
<td>Injury accidents per million vehicle-km.</td>
<td>0,33 (Inner city 2004 = 0,54)</td>
</tr>
<tr>
<td>Traffic volume and composition</td>
<td>Heavy and very mixed traffic.</td>
</tr>
<tr>
<td>Typical solutions for urban streets</td>
<td>Road/street with level crossings, little or no pedestrian safety measures, no bicycle facilities and speed level of 60 km/h or more. Bus and tram stops in the middle of wide streets. Suboptimal street lighting.</td>
</tr>
<tr>
<td>Car parking solutions</td>
<td>Cross street parking in streets with heavy and/or fast car traffic. Mixed traffic and complex vehicle movements in a complicated environment.</td>
</tr>
<tr>
<td>Operation and maintenance of streets and roads</td>
<td>At approximately to-day’s level of accident-preventing maintenance in Oslo, or lower quality.</td>
</tr>
<tr>
<td>Feeling of risk of traffic accident</td>
<td>Fear of traffic accidents affects mode choice. Many avoid cycling. Elderly and children make less use of walking and urban public space.</td>
</tr>
<tr>
<td>Urban environment factor</td>
<td>Level of environment quality</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td><strong>Aspects of evaluation</strong></td>
<td><strong>Low</strong></td>
</tr>
<tr>
<td><strong>5. Little violence and vandalism</strong></td>
<td>Little security</td>
</tr>
<tr>
<td>Risk of experiencing violence and vandalism</td>
<td>Violence and anti-social behaviour is a significant problem requiring expensive countermeasures.</td>
</tr>
<tr>
<td>Social control and surveillance</td>
<td>Rather desolate area, easy for criminals to work in disguise. Need for special control measures, with continuous surveillance and the closure of public areas at night.</td>
</tr>
<tr>
<td>Responsibility for different parts of the area</td>
<td>Unclear responsibilities and little engagement in security.</td>
</tr>
<tr>
<td>Feeling of safety against violence and vandalism</td>
<td>Fear of violence and anti-social behaviour reduces peoples’ use of public areas, even at daytime.</td>
</tr>
<tr>
<td><strong>6. Clean air</strong></td>
<td>Un satisfactory air quality</td>
</tr>
<tr>
<td>Concentrations of air pollutants, refer to figures in the air quality regulations</td>
<td>Minimum requirements are defined in the national air quality regulations.</td>
</tr>
<tr>
<td>Percentage of residents annoyed by air pollution</td>
<td>Over 60 percent.</td>
</tr>
<tr>
<td>Air circulation and ventilation</td>
<td>Bad local air circulation due to barriers and narrow street space. Local climate with frequent inversions.</td>
</tr>
<tr>
<td>Examples of traffic volume in street. (ADT&gt;10. – 15.000 in a narrow street in Oslo is likely to exceed the national air quality goals).</td>
<td>&gt; 8.000 veh. /day (ADT), at any speed and some 10 % heavy vehicles.</td>
</tr>
<tr>
<td><strong>7. Freedom from noise</strong></td>
<td>Unsatisfactory noise conditions</td>
</tr>
<tr>
<td>Noise level, Lₕₑₐₙₑ, at facades</td>
<td>70 dB or more</td>
</tr>
<tr>
<td>Percentage of residents annoyed by traffic noise</td>
<td>Over 60 percent.</td>
</tr>
<tr>
<td>Experience of the sound climate in the urban public space</td>
<td>Noise makes conversation difficult and few natural sounds can be heard.</td>
</tr>
<tr>
<td>Examples of traffic volume in street (ADT)</td>
<td>&gt; 3.000 veh. /day, at any speed and some 10 % heavy vehicles.</td>
</tr>
<tr>
<td>Urban environment factor</td>
<td>Level of environment quality</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td><strong>Aspects of evaluation</strong></td>
<td><strong>Low</strong></td>
</tr>
<tr>
<td>Play environment</td>
<td>Little access to play areas without crossing heavy or fast car traffic. Dwellings in streets with car traffic speeds above 30 km/h.</td>
</tr>
<tr>
<td>School routes</td>
<td>School children must cross road with more than</td>
</tr>
<tr>
<td>Quality of experience for children</td>
<td>Mixed traffic with heavy car traffic, on-street car parking and few safety measures for children in the urban public space. Insecure social environment with little social control for the benefit of children and teenagers.</td>
</tr>
<tr>
<td><strong>9. Continuous urban quarters</strong></td>
<td>Divided quarters</td>
</tr>
<tr>
<td>Barriers between different quarters in an urban district</td>
<td>Residential areas and urban quarters are divided by heavy car traffic, infrastructure, closed areas or “dead” facades.</td>
</tr>
<tr>
<td>Percentage of pedestrians that have to wait for cars when crossing car traffic</td>
<td>&gt; 75 %</td>
</tr>
<tr>
<td>Facilities for crossing car traffic on foot</td>
<td>Fences and detours for pedestrians. Standard traffic signal regulations.</td>
</tr>
<tr>
<td>Pattern of social contacts in the area</td>
<td>Barriers are so strong that they reduce social contacts in the area.</td>
</tr>
<tr>
<td>Example of car traffic volume in street/road through the urban quarter</td>
<td>&gt; 8.000 veh. /day (ADT), 12.000 in a traffic calmed street.</td>
</tr>
<tr>
<td><strong>10. Rich vegetation</strong></td>
<td>Low quality</td>
</tr>
<tr>
<td>Ecology</td>
<td>Little or no greenery. Few plant and animal specimens. Little variation in nature.</td>
</tr>
<tr>
<td>Urban landscape</td>
<td>No or little and random use of vegetation.</td>
</tr>
<tr>
<td>Urban environment factor</td>
<td>Aspects of evaluation</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td><strong>11. Water</strong></td>
<td></td>
</tr>
<tr>
<td>Ecology</td>
<td>Low quality</td>
</tr>
<tr>
<td></td>
<td>All streams in pipes under ground.</td>
</tr>
<tr>
<td>Urban landscape</td>
<td>No, or only random use of water elements.</td>
</tr>
<tr>
<td><strong>12. Comfortable local climate</strong></td>
<td>Low quality</td>
</tr>
<tr>
<td>Sun and shade</td>
<td>Little sun and much shadow in large parts of the year.</td>
</tr>
<tr>
<td>Wind</td>
<td>Much wind due to the design of houses, e.g. turbulence from tall buildings.</td>
</tr>
<tr>
<td>Quality of urban experience</td>
<td>Unattractive for longer stay in the public open space.</td>
</tr>
<tr>
<td><strong>13. Strong place identity</strong></td>
<td>No special identity of place</td>
</tr>
<tr>
<td>Urban landscape</td>
<td>Diffuse place with little specific character.</td>
</tr>
<tr>
<td>Historical identity</td>
<td>No or little concern.</td>
</tr>
<tr>
<td>Other cultural identity</td>
<td>Nothing special.</td>
</tr>
<tr>
<td><strong>14. Rich cultural environment</strong></td>
<td>Low quality</td>
</tr>
<tr>
<td>Historical heritage</td>
<td>Nothing special.</td>
</tr>
<tr>
<td>Buildings</td>
<td>Mediocre quality buildings without a distinct relation to the urban place.</td>
</tr>
<tr>
<td>Urban open space</td>
<td>Little structure and without historical connections, with random function, form and use of materials.</td>
</tr>
<tr>
<td>Urban environment factor</td>
<td>Level of environment quality</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td><strong>Aspects of evaluation</strong></td>
<td><strong>Low</strong></td>
</tr>
<tr>
<td><strong>15. High esthetical quality</strong></td>
<td>Low quality</td>
</tr>
<tr>
<td>Scale and proportions</td>
<td>Random.</td>
</tr>
<tr>
<td>Form</td>
<td>Random.</td>
</tr>
<tr>
<td>Use of materials</td>
<td>Simple materials, randomly used.</td>
</tr>
<tr>
<td>Colours</td>
<td>Random and dull.</td>
</tr>
<tr>
<td>Equipment and decorations</td>
<td>Little more than the necessary.</td>
</tr>
<tr>
<td>Variation and experience</td>
<td>Monotonous.</td>
</tr>
<tr>
<td><strong>16. High quality operation and maintenance</strong></td>
<td>Low quality</td>
</tr>
<tr>
<td>Cleaning of streets and public spaces</td>
<td>Infrequent cleaning.</td>
</tr>
<tr>
<td>Repairs</td>
<td>Repairs 1-2 times per year or less often.</td>
</tr>
<tr>
<td><strong>17. Little energy use and small emissions of greenhouse gases</strong></td>
<td>Not sustainable</td>
</tr>
</tbody>
</table>

Vehicle mileage based on non-renewable energy; 2030 in relation to 1990:
- The Oslo region in total
  - Growth
  - "Oslo package 3" – transport policy measures

Example of measures towards 2025 in the Oslo region
- Moderate road pricing, such as in Stockholm and London
- Strong road pricing and upgrading of public transport.

The table above should be seen as a first draft of a cheque list for the design of streets and urban places. The proposed definitions of urban environment quality in the table should not be seen as a final and authoritative list, and many of the factors mentioned will need subjective judgements, although hopefully they should reflect good professional practice. But they can serve as a basis for public and professional discussion of the level of environmental quality that should be aimed at in different types of areas in the city.

By combining such a discussion in a particular city, with further analysis of the criteria, and by looking into examples of ‘good practice’, one might be able to develop a broad, common understanding of what constitutes a environment friendly city and transport system. Then we have a much better starting point for analysis and discussion of the principles of urban transport network design.

**Different urban functions and places have different requirements**

Having established a yardstick for urban environment quality, it is evident that the environmental quality requirements cannot be uniformly applied to the whole city region. The environmental objectives must be somewhat adjusted to the urban functions in different areas of the region.
The Oslo region study suggested that the type and level of urban quality required for an urban street should be adjusted to the type of urban place function, following the principle idea of the ARTISTS project that urban place requirements must be considered together with link functions.

A simple typology with six different types of streets and urban places were described, as a basis for further discussion of the environmental qualities that are desirable in different types of urban places:

− **Major shopping and public activity streets and squares**, including pedestrian streets in the city centre. The city’s (and the country’s) main streets and parade streets are included in this group, which contains the most intensive urban life of the city’s public spaces.

− **Parks and recreation areas**, i.e. ”green” meeting places and places of peace in the bustling city.

− **Nodes of interchange**, i.e. busy traffic points where large numbers of public transport users change between different lines and modes of transport, where functional and attractive solutions for these users are critical for the competitiveness of the city’s public transport system.

− **Residential streets and roads**, i.e. streets and roads where the requirements of dwelling functions, schools, kindergartens, hospitals, old peoples’ homes and so on are the prime concerns when the objectives of environmental quality are being defined. This type of area includes mixed urban development with a significant proportion of residential functions.

− **Business areas**, i.e. the rest of the streets and roads that are dominated by office functions, industry and warehouses, and other functions where the environmental requirements usually are different to those of typical residential areas.

− **Main roads**, which is the part of the road and street network which should have efficient, motorized road transport as its absolutely main function, but still must be designed with due concern for the environment and the travellers’ experience of the urban environment.

Even more differentiated schemes can be conceived, but then the whole scheme of environmental quality requirements soon becomes very complicated and more difficult to communicate in the urban planning process.

**Many parameters determine environmental quality**

From the table in figure 31 the following conclusions can be drawn:

− If one wants to create a truly environment friendly city with a sustainable urban transport system, rather strong restrictions on to-days’ car traffic are needed.

− High quality urban traffic environment can only be created by the combination of several different means, combining traffic management with urban design and adapting the transport system to the different urban functions it serves and passes through.

− The most important traffic variables that affect environmental quality are the volume, speed and mileage of car traffic. The impact of car traffic
volume and speed will depend on the design of the streets and roads, and the urban functions and design along the car traffic system.

- There cannot be any clear cut answer to the question of which network design principles that should be recommended to achieve the highest level of urban environment quality.

Having this type of criteria for the evaluation of urban planning and road transport networks, it becomes evident that the earlier discussion of the principles of integration or segregation in urban network design is rather irrelevant and far too simplistic if one wants to promote the goal of a sustainable and environment friendly city. Advice on the design of road transport networks in urban areas must have a much stronger empirical basis than what has been presented in the arguments by the advocates of traffic integration, the new urbanism movement and the critics of traditional urban road network design.

However, it is not enough to define the environmental requirements of different urban functions. One must also understand the connections between environment and car traffic. Therefore, in the next subchapter we look at some of the lessons gained from traffic calming schemes in a number of countries in the last 30 years (chapter 4.2).

4.2 Lessons from studies of traffic calming

Clearly, when discussing the future principles of urban road network design it is useful to look at the large amount of experience and hard evidence that has been gained from various forms of traffic calming in urban areas all over the Western world since the 1970’s.

In our analysis of the arguments for traffic integration and fully open networks for car traffic in chapter 3, we were rather surprised that this evidence has not been properly analysed by the critics of common practice in urban traffic planning. In this chapter we will summarize some of the most important results. The analysis is based on some existing reviews and planning guidance reports about traffic calming from various countries.

Definitions and different types of traffic calming

Traffic calming has been defined in various ways by different authors and studies. In this study the term is used in a broad sense, similar to the following definition recommended by the Institute of Transportation Engineers (USA; Lockwood 1997):

‘Traffic calming is the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behaviour, and improve conditions for non-motorized street users.’

An equally broad definition was applied by the SWOV Institute for Road Safety Research in a report contracted by the Swedish National Road Administration. In their concise overview of knowledge of and experiences with traffic calming in urban areas, both on a technical level and on a policy level, they used the following definition (Van Schrage (ed.) 2003):
‘Traffic calming refers to a combination of network planning and engineering measures to enhance road safety as well as other aspects of liveability for the citizens.’

The study ascertains that much is known about the technical opportunities of urban traffic calming, and that this is effective in reducing car speeds, car traffic volumes, and road traffic accidents. Van Schrage (ed.; 2003) also confirms the recommendation of other guides on traffic calming that public participation, information and education can strengthen the positive effects of traffic calming, and contribute substantially to the level of public support for such measures. Public information as a stand-alone measure generally does not influence behaviour to a large extent, but it does add value to other measures such as road engineering measures. Education also has the advantage that the effects of measures and/or particular behaviour strategies can be experienced and trained in practice.

The main focus of most traffic calming schemes has been on traffic safety and environmental improvements on residential streets and roads. This was the case of the Dutch ‘Woonerfs’ pioneered by the City of Delft in the early 1970’s, and of the Swedish and later Scandinavian traffic management schemes (‘Trafik(k)sanering’ in Swedish/Danish/Norwegian) of the same decade.

In the UK this type of traffic management was partly described in the Buchanan report that used the term ‘Environmental area’ for traffic calmed area between distributor roads. Traffic calming is now being promoted under the heading of ‘Home Zones’ (Department for Transport 2005). Even in the USA (e.g. Bonneson et al. 2000), and in Australia, traffic calming in the meaning of traffic regulation and management in residential areas, is now mainstream practice.

But also many main roads and streets have been the object of traffic calming measures. This was first the case for main through roads in villages (e.g. in the 1980’s in Denmark, Norway and Germany). Some state highways were treated with various types of speed reduction measures, even humps. But soon similar types of measures were applied to main streets with rather heavy traffic (up to some 20.-25.000 veh. /day) in cities, probably with Germany, France and Denmark as the pioneering countries in the 1980s and 1990s. In Germany, the term for Traffic calming – ‘Verkehrs-beruhigung’ – incorporates both residential street and main street schemes.

In France, as in other countries, this started as a traffic safety programme (‘Ville secure’), but there traffic calming soon also developed into an urban improvement idea with focus on the beautification and improved liveability of urban areas that have been, literally, ‘run down’ by heavy car traffic. Now this is an increasingly more important aspect of traffic calming, which we will comment upon later in this chapter.

Common to all these schemes, however, are the use of traffic calming techniques that, according to Bonneson et al (2000), ‘rely on the laws of physics to slow traffic down. They are self-enforcing and do not explicitly reroute drivers.’ However often the intended, or even unintended, effect is to reroute car traffic by the use of some type of traffic restriction or by
making operational improvements to alternative routes. This was, for instance, the case of the Scandinavian traffic management schemes in residential areas in the 1970’s and later.

Traffic restrictions in addition to the speed reducing measures, include lane closure, and turn movement prohibition, one-way regulations and the closing of street sections to car traffic. Improvements to alternative routes include realignment, increased capacity, or improved traffic progression.

It is sometimes useful to distinguish between single street traffic calming, and area-wide traffic calming. However, in most urban situations traffic regulation measures on a single street will indirectly influence car traffic on other streets in the vicinity, sometimes only marginally, but often more significantly.

Furthermore, gradually we are seeing more urban traffic planning programmes that look upon urban wide, traffic calming as one of the means to reduce the volume of motorized traffic by giving less space and road capacity to cars and providing safe and attractive facilities for alternative transport modes such as cycling, walking and priority measures for public transport.

**Large benefits from low driving speeds**
A major reason for traffic calming becoming an important part of modern traffic planning is that society has gradually understood the great benefits of keeping driving speed low on most of the urban street network. In comparison, forsaking some, often quite short, stretches of high speed driving is now seen as a small price to pay inside towns and city districts. The benefits of car use are not significantly reduced by introducing large areas of 30 km/h-zones.

Moderate driving speed is now seen as a major policy measure in traffic safety policy. For instance, this is underlined in a recent, comprehensive Dutch overview of traffic safety policy (Wegman and Aarts (ed.) 2006).

Speed reduction on residential and distributor roads results in several effects:

- Improved traffic safety
- Reduced car traffic, mainly due to through traffic moving to other routes (effects on total car traffic is discussed in chapter 4.4)
- Less need for road space
- Easier for pedestrians (and cyclists) to cross car traffic
- Softer driving and less energy use
- Less traffic noise exposure
- Reduced air pollution (?)
- Improve the relative attractiveness of the environment friendly transport modes in relation to car use

The relations between traffic volume and speed on the one side, and different urban environment factors on the other, are fairly well
understood. We do not have the resources for a full investigation of the literature, so we will only refer to the most easily available evidence.

It is interesting to note that reduction in acceptable speed levels represents a return to the urban traffic speed limits that were in operation before the explosive growth in car ownership started in the 1950’s and 1960’s. The idea of slow speed driving in urban areas is no new invention.

In the early years of the car society, there was strong opposition against high speed motor traffic. The main arguments against the higher speed limits that the car lobby wanted were traffic safety for other road users and disturbances of city life. The opposition was stronger in the more densely urbanised European countries, in particular United Kingdom, than in a frontier and rural country like the United States of America. This difference in speed policy can be seen as one of the reasons for Europe being much later in the adaptation to the car society than the USA, a difference that to-day has far-reaching consequences for modern society’s attempts to deal with the challenges of sustainable cities and transport.

**Improved traffic safety**

The main reason for introducing speed reduction measures is the concern for traffic safety. The basic connection between speed and stopping distance of cars is shown in figure 33.

This relation should be seen together with knowledge about the consequences for a pedestrian of being hit by a running car, as shown in figure 34: Above a speed of some 30 km/h the risk of being killed as a pedestrian increases very significantly. We also see that there is little chance of survival if the pedestrian is hit at a speed above some 60 km/h.
Research on traffic calming measures that reduce the speed of traffic has confirmed that large benefits in traffic safety are gained. Van Schaden (ed.; 2003) concluded a review of evaluation studies of residential streets that they ‘generally report on substantial decreases in speed, traffic volumes, and accidents, although there is a large variation in effects’.

Norwegian meta-analyses of the results of a large number of national and international evaluation studies are summarized in the Traffic Safety Handbook from the Institute of Transport Economics. Some of the main results are (Elvik and Vaa, 2006):

- There is a clear relationship between speed limit and traffic accidents on both rural and urban roads.
- In cases where speed limits have been increased, traffic accidents also increased. For a change of speed limit from 40 to 50 km/h the average number of injury accidents was increased by 12 percent. For changes in speed limit from below 90 to more than 90 km/h the average speed
increased by some 17 percent, injury accidents increased by 17 percent and fatal accidents by 21 percent.

- In most cases where speed limits have been introduced or lowered, traffic accidents have been reduced. As an average for all studies average speed was reduced by 14 percent, injury accidents by 14 percent and fatal accidents by 15 percent. Speed limit reductions from 60 to 40 km/h or from 50 to 30 km/h had an average effect of 48 percent reduction in injury accidents.

- Physical speed humps on urban and residential roads, usually in combination with speed limits below 50 km/h, reduced average speed by some 33 percent (from 36.4 to 24.4 km/h) and the number of injury accidents by 48 percent. The speed humps also affected driving speed and accidents on adjacent roads without such measures.

- As an average for 30 km/h zones with speed reduction measures, injury accidents was reduced by 27 percent.

- Rumble strips before junctions reduced injury accidents at these junctions by 33 percent.

- All these effects are measures of changes in accident risk for a given traffic volume. Speed reduction measures often also affect route choice and traffic volume, normally with additional safety benefits.

In UK, ‘Home zone’ projects of traffic calming in local residential streets have achieved significant speed reductions. Over half of the schemes reported achieved speed reductions between 10 and 15 miles per hour (Department for Transport 2005).

Bonneson et al (2000) analysed data from many studies internationally, and found the effects of three different types of calming devices as shown in figure 35. Looking at the effect of speed reductions (by humps) on residential streets, streets with a parallel alternative route had some 27 percent reduction in traffic volume, although the average speed reduction was the same on streets without an alternative route (27-31 percent reduction from 36-37 miles/hour).

![Figure 35. Expected effectiveness of selected traffic calming devices (Bonneson et al 2000, table 14).](image)

It is important to note that the safety effect of speed reductions are just as significant on main roads and distributor roads as on roads in residential areas.
'Safe' speed or optimal speed?

When traffic safety is a high priority goal, such as the ‘zero accident vision’ programme of Sweden and similar traffic safety ambitions in Norway, then low speed is one of the most efficient means.

The recommended principles for ‘safe roads’ are, in the words of the Dutch road safety review (Wegman and Aarts (ed.) 2006, p.36):

‘low speeds where vulnerable road users mix with car traffic. Higher speeds are allowable only where high-speed traffic cannot get into conflict. Where higher speeds are allowed, only vehicle types that are equipped for these speeds, and which provide sufficient protection in case of a crash are permitted.’

Wegman and Aarts (ed.; 2006) discussed the recommended ‘safe’ speed limits of Tingvall10 and Haworth (1999) for different conflict situations. The starting point for these recommendations was modern, well-equipped cars and 100 percent use of seat belts and child restraint systems. However, according to Wegman and Aarts, crash tests have shown that the safety requirements for cars should be stricter than implied by Tingvall and Haworth. Further, the car fleet does not (yet) consist of the best designed cars and the use of protection measures is not 100 percent. And the speeds are not valid for crashes with heavy vehicles such as lorries, or for motor cycle accidents. Wegman and Aarts therefore conclude that the safe speed recommendations must be lower than those proposed by Tingvall and Haworth.

In addition to the points made by Wegman and Aarts, one should take account of other environmental benefits of low speed and improved conditions for other road users, which we discuss in the next sections. Also the disbenefits of reduced speed should be considered, i.e. the increase of travel time for car users.

In Sweden, Finland and Norway, several studies have been made in order to calculate social-economic optimal speed limits, mainly on roads outside urban areas. They have been reviewed by Elvik and Vaa (2006), and the conclusion is that the optimal speed of car traffic is lower than the existing speed limits on most roads. Due to a gradual increase in the value put on human life and social costs of traffic accidents, Swedish studies indicated that much lower speed should be chosen today than in the earlier studies.

A cost-benefit analysis for Norway in 1995 showed that there is no social-economic benefit from higher speed limits on motorways than 90 km/h on standard A motorways (full dual carriageway) and 80 km/h on standard B motorways (reduced standard). It is profitable for society to reduce the general speed limit on rural roads in Norway from 80 to 70 km/h and in the winter season speed limits should be reduced by additional 10 km/h in comparison with the general speed limits.

This study takes account of air pollution effects (also a value on CO2-emissions) in addition to accident costs, travel time and fuel costs. But it

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10 According to Wegman and Aarts (ed.; 2006), Clas Tingvall is one of the founding fathers of the Zero Vision in Sweden.
does not consider any benefits from traffic noise reduction, or effects on other road users, which are important in urban areas.

From the studies of ‘safe speed’ and analyses of ‘optimal speed’ we can suggest the following conclusions for the sustainable city and transport system (including the Zero serious injury accident vision):

– On roads with possible conflicts between cars and unprotected road users, i.e. on all urban roads with mixed traffic, speed limits should not be higher than 30 km/h. Therefore the general urban speed limit should be 30 km/h.

– Speed levels should be even lower than this in the most vulnerable urban streets and areas.

– At intersections with possible transverse conflicts between cars, i.e. at all junctions with left-turning traffic, the speed limit should be 40 km/h or lower.

– On roads with possible frontal conflicts between cars, i.e. all roads without a barrier between the two driving directions, the speed limit should be less than 70 km/h, particularly under bad driving conditions.

– Roads with no possible frontal or transverse conflicts between road users, i.e. full standard, grade separated motorways, should not have a speed limit above 90 km/h, and this should be reduced to at least 80 or 70 km/h under bad driving conditions.

However, it is important to note that the desired speed reductions cannot be achieved in practice without changes in road design practices and adaptations in the traffic environment of car drivers, and/or much stricter and automatic control of traffic speed on roads and streets.

A recent Swedish test of car drivers’ speed in different urban environments showed that independently of the signed speed limit (30, 40 or 50 km/h), the drivers choice of speed is strongly affected by the road and traffic environment. Factors that influenced the speed chosen were road width, visibility and the amount of traffic. Drivers who were unfamiliar with the traffic environment drove faster on some road sections than those who knew the local area well (Törnros et al. 2006).

Automatic traffic speed control has been in operation in Norway for more than 20 years, and has been proved to be an efficient traffic safety measure. Speed measurements before and after installations of control cameras have shown that the average speed reduction is 6 km/h on the road sections were they are put up, and a somewhat larger reduction close to the camera boxes. The boxes are clearly signed and they are being put up on road sections were many drive much faster than the speed limit. The number of injury accidents has been reduced by some 30 percent on the roads where they have been put up. Opinion surveys have shown that approximately 90 percent of car drivers are positive to this form of traffic control (Statens vegvesen 2004).

Reduced car traffic
As already noted, in addition to the speed reductions, traffic calming often results in some reductions in car traffic volume. The effect naturally depends on the amount of through traffic and the attractiveness of alternative routes.
Bonneson (2000) concluded that for residential areas, car traffic typically will be reduced by 5 – 25 percent, compared to the traffic volumes in a conventional road network with 50 km/h speed limit, see figure 35 (earlier in this subchapter).

A Norwegian review of 26 international case studies of traffic calming on main through roads in villages, showed some reductions in traffic volume for almost all projects, and up to 20-40 percent traffic reduction in cases where there existed some other possible routes for the drivers to choose. Speed reductions where mainly in the order of 10-20 percent (Haddeland and Nielsen 1992).

We will later look at how network design may affect route choice, but must stress that the local circumstances always will be decisive for the volume and pattern of car traffic.

**Less need for road space for car traffic**

Low-speed car traffic needs less road space than car traffic at high speed, figure 36. This is due to the fact that shorter distance between cars is needed to provide a certain level of safety, and because drivers manage to drive closer to other vehicles in the same or in the opposite direction.

(Hotzan 1994, p. 141) has made a calculation of the theoretical space demand of cars and public transport at different speeds of travel. At 30 km/h each person in a passenger car (with 1.4 persons) needs 75.3 m², which at 50 km/h is more than doubled to 169 m²/person. In comparison, a person travelling by bus (with 40 % of capacity in use), requires only 4.1 m² at 30 km/h and 8.7 m² at 50 km/h.

Thus, reduced speed will very significantly reduce the amount of road space needed for the motor traffic. With an appropriate road design, a general reduction in urban speed limit from 50 to the above recommended 30 km/h will increase available road space for other road users or urban functions.
**Easier to cross car traffic**

The first immediate effect of reduced speed and narrower lanes is that it becomes easier for pedestrians to cross the street. This fact was used in order to define the concept of environmental capacity in the Buchanan report (Ministry of Transport 1963), and the concept was developed further by Crompton and colleagues (1970 and Gilbert 1988).

The aim was to describe quantitatively the level of conflict, or the quality of the environment, from a pedestrian point of view. “Pedestrian quality” was quantified in order to compare different streets and traffic management schemes. As an example, Buchanan defined different levels of risk or level of conflict for pedestrians crossing car traffic in a street or road, as indicated in figure 37.

<table>
<thead>
<tr>
<th>Proportion vulnerable pedestrians</th>
<th>Safety conditions for pedestrians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small (less than 20 percent)</td>
<td>Good: P = 70 %</td>
</tr>
<tr>
<td>Medium (20 – 50 percent)</td>
<td>Good: P = 60 %</td>
</tr>
<tr>
<td>Large (over 50 percent)</td>
<td>Good: P = 40 %</td>
</tr>
</tbody>
</table>

Figure 37. Level of pedestrian conflict (P) that are considered acceptable for different types of street environments and the for different proportions of extra vulnerable pedestrians, such as small children, elderly, parents with prams, handicapped persons etc. (After Ministry of Transport 1963, p. 205).

The connection between car traffic volume, pedestrian waiting time and the width of the carriageway pedestrians have to cross was established through statistical theory and some traffic observations.

Figure 38 shows this relation for a stochastic, free flowing traffic stream. Later developments also attempted to describe conditions where the cars come in platoons as a result of traffic signal regulations or for other reasons. However, we believe that for practical planning, very detailed and exact calculations might not be needed. The simple relationship could still be used – together with indicators of other environmental factors – in discussions of what level of car traffic that might be environ-mentally acceptable in different streets.

**Softer driving and less energy use**

In undisturbed operations, light vehicles have the smallest fuel consumption when they run at 60 – 70 km/h, and heavy vehicles at approximately 50 km/h (Elvik and Vaa, 2006). Above these speeds fuel consumption per vehicle-km increases with speed, but slower speeds will also result in more use of fuel, unless the style of driving is changed. However, fuel consumption is also a result of how the motor is designed and adjusted. If very high speed no longer continues to be a significant design factor for the car buyers and manufacturers, then it will be easier to design low-fuel vehicles that are optimized for slower average speeds than to-day.
The driving style of most drivers normally changes when a reduction of the speed limit below 50 km/h is introduced and enforced through traffic calming measures that make fast driving uncomfortable. Then most drivers drive softer, with less acceleration and deceleration between junctions and speed reducing measures. Not all drivers keep to the regulated speed limit, but the number of vehicles running at high speed is significantly reduced. The changes in driver behaviour improve traffic safety and reduce the use of energy for the propulsion of vehicles.

Some of this effect takes place spontaneously, and this is more clearly seen when 30 km/h-zones have become widespread, so that the motorists get used to it. In the early years of traffic calming it was claimed that car drivers would speed up between humps or other measures, so that the effect on average speeds would be negligible. This has been proved not to be the case if the street environment is appropriately designed and the distances between measures are not too big. Traffic calming guides give advice on this design question.
Attempts to further strengthen the effects on driving speeds through publicity campaigns and information to motorists, have been made, e.g. by the German motorists’ organisation of ADAC. Professional training of lorry and bus drivers in soft driving is now an established activity among transport operators. With higher fuel prices, also more car owners are likely to take care in their style of driving. The traffic calming measures in the urban street networks and the extension of low speed zones are likely to make this a more common feature of urban motorized traffic.

**Less traffic noise exposure**

With reduced speed, tyre noise from car traffic will be reduced. This is a particularly strong effect when high speeds of 70 – 90 km/h are reduced to 50 – 60 km/h or less. At speeds below 50 km/h the noise from the propulsion system is the main source, and then the style of driving becomes more important.

The general relationship between driving speed and noise from light and heavy motor vehicles is described in figure 40, which also shows the effect of improved vehicles with less noise from the motor in the period 1974 - 1995. This means that speed now is a more significant factor than 20-30 years ago.
A speed reduction on major urban roads from 80 to 60 km/h or from 70 to 50 km/h should, according to this diagram now result in a noise reduction between 3 and 4 dBA. This is equivalent to the noise improvement effect of more than a 50 percent reduction in traffic volume.

A Norwegian literature study (Amundsen 2002) of the effects of a reduction of the speed limit from 80 to 60 km/h on major roads, concluded that the average traffic speed would not be reduced by 20 km/h, but by 5-7 km/h. On the other hand, a one day experiment with the same change in speed limit on a national highway in Oslo in March 2000 resulted in an average speed reduction of 10 km/h.

A similar reduction in signed ‘environmental’ speed limit was introduced on Oslo’s national highway no 4. For 5.5 months during the winter of 2004/2005 the signed speed limit on this congested dual carriageway road was reduced from 80 to 60 km/h. This resulted in an average daily speed reduction of 10 km/h, from 77 to 67 km/h. The measured average noise reduction was some 2 dBA (Statens vegvesen 2005). The results, also in terms of reduced air pollution (see below), were so encouraging that ‘environmental speed limit’ has become a more widely used instrument in traffic environment policy in the City of Oslo.
Also the properties of the road surface influence the noise level from car traffic, and should be considered. German advice on traffic calming takes account of this (Umweltbundesamt 1990). Their research has established the relation between speed, driving style and type of carriage-way surface, figure 41. Significant results in terms of reduced traffic noise can be achieved by an optimal combination of speed reduction measures, soft driving and the right choice of road surface.

![Figure 41. Noise level, dBA at 7.5 m from the vehicles, as a function of the proportion of vehicles with a rough driving style and type of road surface (Vegdirektoratet 1992/ Umweltbundesamt 1990).](image)

A Swedish literature study of the environmental effects of traffic calming (Hedström and Svensson 2003) found a somewhat mixed picture, to a large extent due to the lack of common methods of measurement and definitions of parameters. However, as far as traffic noise is concerned, the following findings are interesting:\(^\text{11}\):

- Traffic speed clearly affects traffic noise (dBA), and traffic calming measures do not in general have any negative effect on noise level.
- Measures which result in very strong decelerations and/or accelerations results in increased noise emission (Our comment: according to Umweltbundesamt 1990, this can be avoided by proper design of traffic calming schemes).
- Redesign of traditional junctions to traffic roundabouts reduces traffic noise.
- Several British monitoring studies of traffic calming measures in residential areas have confirmed that traffic noise has been reduced, and also that perceived noise annoyance has been even more strongly reduced.

\(^{11}\) The references to the original studies are given in Hedström and Svensson 2003).
Even on major through roads with up to 10-20 percent heavy vehicles clear traffic noise reductions have been achieved in UK, Denmark and Sweden. 4 dBA average noise reductions at daytime and 2 dBA at night was the reported effect of road humps on 40 km/h roads in Sweden.

Motor emission level (as opposed to tyre noise) and driving style is most important at speeds below some 50 km/h than at higher speeds. Since indoor noise levels depend more on low frequency sound, reductions in urban traffic speed has less effect on indoor noise than on noise levels in the streets and outside buildings.

A Norwegian review of 22 international case studies of traffic calming on main through roads in villages, showed some 1-3 dBA reductions in average noise level with typical speed reductions of 10-20 percent (Haddeland and Nielsen 1992).

Internationally, further research and development is taking place in order to make noise-absorbing asphalt surfaces that are able to satisfy normal wear-and-tear requirements, so that no extra road dust and air pollution is created. Recently the Swedish road building firm Skanska was given the Swedish Road Administration’s Environment prize for a new asphalt product that creates only half as much noise as conventional asphalt (www.vv.se).

Reduced air pollution emissions

In general, exhaust emissions are proportional to the level of fuel consumption. Therefore one might assume that air pollution will decrease for most speed reductions down to some 50-60 km/h. However motor and fuel technology, driving style and the design of the traffic system make the relationships between speed and air pollution very complicated, and these relations are different for different types of pollutants.

As an illustration, figure 42 tells us that there is a very significant difference between cars with and without catalytic cleaning. With the latter or equivalent, now compulsory technology installed, it looks as if speed no longer is an important factor influencing the emissions of carbon monoxide, nitrogen oxides and hydrocarbons from cars. For other types of vehicles, motor and fuel technologies these relationships are likely to be different, and they are likely to change over time as new vehicles replace old ones.

For all these reasons, one must be extremely careful when using research results from earlier studies. Even without clarifying the differences between old and recent studies, the already mentioned Swedish literature study of the environmental effects of traffic calming (Hedström and Svensson 2003) found it difficult to draw conclusions. Still, we find the following results interesting12:

– It is important to use measures of speed reduction that encourage smooth driving at low speed, and discourages driving with large variations in speed. At speeds below 50 km/h the style of driving is more important than the average speed. Consistent, area-wide traffic calming measures will contribute to soft driving, less fuel consumption and reduced emissions.

12 As for traffic noise, we refer the reader to Hedström and Svensson (2003) for their original references.
Studies of the area-wide effects of traffic calming (taking into account changes in traffic flows) have shown clear reductions (up to 30 percent) in emissions of nitrogen oxides, but it is difficult to draw conclusions about the effects on emissions of carbon monoxide and hydrocarbons.

In Graz 30 km/h was introduced as the general speed limit on all streets except main roads. Measurements with test cars and calculations in order to reflect the actual composition of motor and fuel types concluded that emissions of CO, CO$_2$, HC and NO$_x$ was clearly reduced on the 30 km/h streets, but also in the city as a whole. Also emission measurements with test vehicles in Buxtehude concluded that the 30 km/h zones resulted in reduced emissions of CO, HC and NO$_x$, but no change in fuel consumption.

Various studies indicate that the propulsion system of most car models are not optimized for low speed driving, but it can be expected that this will be improved through new technological solutions.

As mentioned in the section on traffic noise, an 'environment speed limit' has been introduced in the winter months on some of the national roads in the City of Oslo, where the speed limit has been reduced from 80 to 60 km/h. Here, the concern is not only exhaust emissions, but also the dust and fine particles from the road surface which is thrown up in the air by fast moving traffic. A theoretical analysis (Amundsen 2002) concluded that the exhaust emissions of CO, NO$_x$ and particles would increase, while the amount of particles in the air along the road would be reduced due to expected reduction in average traffic speed of up to 10 km/h.
calculations were based on the emission factors in relation to speed in the national traffic emission model ("VLUFT").

However, when the reduced speed limit from 80 to 60 km/h was realised in practice on national road no 4, very significant improvements in air quality was measured, in addition to the noise reduction mentioned earlier. Despite the fact that average speed was reduced by ‘only’ 10 km/h, particulate matter concentrations in the air along the road was reduced by as much as 39 percent (other air quality stations were used to control for external factors).

The response from the public was more positive than feared, and an opinion survey 80 percent of respondents said that the environmental speed limit was an acceptable measure if it resulted in improved air quality. The reduction in speed limit did not cause any new congestion of traffic flow (Statens vegvesen 2005). The results, also in terms of reduced traffic noise (see above), were so encouraging that 'environmental speed limit' has become a more widely used instrument in traffic environment policy in the City of Oslo.

Our conclusion is that even in relation to air pollution from motor traffic, a low speed urban traffic system is to be recommended.

**Improved relative attractiveness of environment friendly transport modes**

The last, but not he least important, environmental and transport benefit from a low speed road system for cars is the effect it can have on peoples’ choice of transport modes and travel patterns. This effect has four different sources:

First, car journeys will take a little more time, even if this effect probably is smaller than most motorists tend to believe. This will make alternative modes marginally more attractive, in particular for short journeys.

Second, more of existing road and street space (see above) can be used for pedestrians, cyclists and public transport, making these alternative modes more attractive.

Third, crossing of car traffic will be safer and faster with less delay (see above).

Fourth, reduced car traffic volume (as demonstrated in many traffic calming studies) will reduce environmental disturbances and delays for pedestrians, cyclists and public transport.

Taken separately for a single environmental area, each of these effects may be quite small. But taken together and applied all over a large urban area, the total effect is likely to be significant.

In the long term, many opportunities for the physical changes in the design of the traffic system and the competition between modes can be exploited. We believe that, together with other measures, this can become a key factor in redirecting the future of urban traffic into a more sustainable direction.
Both traffic integration and segregation is necessary
Speed reduction is not the only policy measure that is needed to create a sustainable and environment friendly traffic system. The questions of the design of the road structure and the discussion of integration and segregation between different types of traffic must still be analysed.

An analysis of the question of network pattern is made by the Dutch traffic safety review (van Schagen (ed.) 2003). They discuss the different merits of the two main types of solutions for residential areas that formed the starting point of our study:

Segregation, i.e. street network based on the principle of complete segregation of pedestrians and motorized traffic.

Although this principle has been shown to have a significant positive effect on traffic accident rates, it has been claimed that such networks are expensive, that they make good public transport services difficult, that the position of cyclists, mopeds etc. in the traffic system is unclear, that these solutions can only be applied when developing new areas, and that they make it difficult to mix urban different types of urban functions in an area.

Integration, i.e. letting pedestrians and motor vehicles share the residential street surfaces by encouraging, partly enforcing, drivers to drive at walking pace and give precedence to vulnerable road users in the street, in particular children.

Also this principle has been shown to give substantial reductions in accidents when compared to conventional street solutions and traffic regulations. Reduced driving speed is the main reason for this effect. It has also lead to reductions in through traffic. However, one can also argue that the principle of integration is expensive to build and maintain (our addition), that there are operational and legal problems with some of the technical measures, and that the road space needed for the concept is not always sufficient. (We will add that) also the quality of safety for small children in these streets is a source of criticism.

We will argue that both these two principles of road network design are needed in the sustainable and ‘safe’ city. It is the extreme applications of both principles that should be avoided.

We will refer to some of the literature that supports our conclusion. We do this with the background knowledge that it is a misunderstanding to think that the principle of traffic integration excludes the use of segregation. This can be seen even from the beginning of modern traffic calming, as pioneered in the Netherlands in the 1970’s and presented internationally by Vahl and Giskes (1990).13

At the detailed street design level, traffic calming uses a combination of streets where vehicles and pedestrians use the same road surfaces, with streets where the street space is divided into separate sections for different street uses. Most of the street surface in a traffic calmed area is

13 They received the first Volvo Traffic Safety Award in 1986. The 1990-book is the English version of earlier reports presenting their ideas in Dutch and French.
in fact designed with more or less specialized use for different purposes: A carriageway surface for motor traffic, pavements for pedestrians, cycle lanes for bicycle traffic, separate parking places for cars and bicycles, loading bays for delivery vehicles, etc. It is really the pedestrians’ freedom to use and cross all these areas that is different from conventional street design, in addition to the different measures used to slow down the speed of car traffic as described earlier.

At the road network level, traffic calming still allows for pedestrians and cyclists being segregated from other traffic by roads where motor traffic is prohibited, and of course grade-separated crossings of fast and heavy road traffic is part of this network design.

From this follows that the hierarchical differentiation of the car road system is also a significant feature of the traffic calmed street and road system.

All this is quite clear when one looks at the traffic system design principles advocated by Vahl and Giskes (1990). They, quite rightly criticise the land-consuming, over dimensioned segregated and hierarchical road systems which have been built according to the road network principle of the 1960’s, and the segregation of different urban activities such as living, working, commercial activities, recreation and traffic. It is however, worth noting that the authors state the basic aim of their work in these terms:

‘Day after day, year after year, cities and villages are destroyed in order to let motorized traffic pass through as fast and comfortable as possible...Nobody of course wants to destroy cities and villages. Nobody wants to cause accidents. Still we all accept the disintegration of urban fabric and the loss of many lives. The bombardment of towns and villages by motor vehicles must come to an end. We will have to repair and reconstruct the lost qualities of urban life and build cities based on the priority of people on foot over cars. Pedestrians should be able to use urban open spaces freely everywhere...

It is essential to reduce traffic speeds here and now. But that is not enough. It will be necessary to formulate a reconstruction programme, as if a car bombardment had taken place. This will require a great deal of time, attention and money. Priority must be given to the adaptation or complete reconstruction of places and neighbourhoods that have been eroded by (sometimes imaginary) automobile flows. It will be important to refocus on a design that blends with the village or town environment. It is essential to introduce coherence between urban planning and traffic engineering. We have to completely restructure our built-up areas...

Cities should be made for people and not for cars. It would therefore be better to adapt cars to city life (even through electronic control devices) instead of the other way around... ’

The topic we are dealing with is basically an urban planning matter, and not a specialized traffic design question. Nevertheless, good understanding of the techniques of traffic safety and environmental design of traffic
is necessary to come up with the right recommendations for a particular case of the sustainable city and transport system.

**For traffic safety it is crucial to segregate vulnerable road users from through-running car traffic**

When recommendations for future urban planning are being made, it is essential to consider the experiences of the very successful traffic safety work of traffic engineers and urban planners in the last 30 or 40 years.

Bonneson et al. (2000) reported in a review of earlier studies:

‘Studies in England, the Netherlands, Germany, and Sweden ...have compared child-involved crash rates in newly-constructed residential areas with those in older areas. These studies indicate that newly-constructed areas have crash rates two to five times lower than the older areas. The lower crash rates were explained by the following factors:

Through traffic is often heavy in old areas, and the street network is more complex. New areas have a more differentiated street network according to traffic function in order to discourage or eliminate cut-through traffic. Also, some new streets include cul-de-sacs.

Older areas often include mixed activities, resulting in some on-street parking. The older areas often lack playgrounds, so children use the streets for playing, biking, and other recreational activities.

New areas have access to numerous playgrounds and green areas that are free from motor vehicle traffic. There are often separated walkways and bicycle paths that lead to school and to other activities of interest for children.’

They also referred to the fact that ‘society cannot adapt children to traffic; society has to adapt traffic to children.’ Studies of children’s capabilities in traffic emphasizes that the nature of children prevents them from handling the demands of traffic and that speed is a strong risk factor for child pedestrian injury. This is a strong argument for not taking an easy way out of the arguments in favour of traffic segregation.

Further, mixing vulnerable road users such as pedestrians and cyclists with large volumes of motorized vehicles at medium or high speed is likely to create many traffic accidents and fatalities. This is clearly documented by accident risk rates for different types of roads and urban environments.

Bonneson et al. (2000) investigated average accident rates on various road classes. For residential local roads and streets they found a rate of 1.6 fatal crashes pr 100 million vehicle-miles and a rate of 1.1 on collector roads. So the accident risk of a car journey might increase by some 50 percent or more when drivers turn off the main road to the local street not designed for through traffic. A large proportion of this increase in accidents would be pedestrians and children in the residential areas, according to the authors’ review of the literature.

The same point, but with greater differences in accident risk levels, can be made on the basis of traffic risk data from Norwegian roads, which
illustrate the large differences in accident risk we have on different types of roads and traffic environments.

From figure 43 we see that the existing speed limits on urban and local roads in Norway (one of the countries in the world with the lowest accident rates and rather strict speed limits) are not so restrictive that they compensate for the increased risk of injuring road users when driving through dense urban areas. At the extreme, a car journey through a local residential or urban street has a risk of traffic injury that is ten times that of car running on a class A motorway with a speed limit of 90 km/h. In relation to a major, mixed traffic, semi-urban road with a speed limit of some 60 – 70 km/h, the risk is 3-5 times higher on the typical local road.

Figure 43. Average injury accident risk on different classes of streets and roads in Norway 1991-94. Police reported injury accidents per million vehicle-kilometres. Classification of roads according to rural/semi-urban/urban environment, national/county and local roads, and road standard/speed limit. (Source: Elvik and Vaa, 2006).

<table>
<thead>
<tr>
<th>Trafikkmiljø</th>
<th>Vegtype</th>
<th>Vegstandard/ fartsgrense</th>
<th>Personskadeulykker pr million kjøretøym</th>
<th>Trafikkmiljø</th>
<th>Vegtype</th>
<th>Vegstandard/ fartsgrense</th>
<th>Personskadeulykker pr million kjøretøym</th>
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<tr>
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<td>Middels tett</td>
<td>Riksveg</td>
<td>60 km/t</td>
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<td></td>
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<td>Motorveg-B</td>
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<td>Øvrig 90 km/t</td>
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<td>Fylkesveg 60 el 50 km/t</td>
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<td></td>
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<td>80 km/t</td>
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<td>Kommunal veg 50, 40, 30 km/t</td>
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<td>70 km/t</td>
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<td>80, 70 km/t</td>
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<td>Tett</td>
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<td>Boliggate uten fartsdemping</td>
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<td>Alle</td>
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More detailed data from the inner city of Oslo tell the same story, figure 4414. Local streets that have significant through traffic had an injury accident risk per vehicle-kilometre that was three times that of the main roads in the inner city. Also on the local streets with little car traffic, i.e. less than 3 000 vehicles/day, the accident rate was significantly higher than on the major roads and streets. We should bear in mind that this picture is despite of the rather slow car traffic in the local streets.

Moreover, the data from the streets of Oslo inner city showed that the vulnerable road users had to bear a large part of the burden of the reduced traffic safety on local roads.

14 The data are a bit old, but more recent figures for different types of streets in Oslo are not available. However, there is little reason to believe that the general picture has been significantly changed, except for parts of the city’s main road system which now have large sections built as tunnels under the city. This has probably increased the differences in accident rates and the safety benefits of taking car traffic out of city streets and onto the main road system.
Having this type of risk data in mind, it comes as no surprise that there is much to be gained in traffic safety by designing a road and street system that takes through traffic out of local streets and concentrates as much of the motor traffic as possible to the main roads and streets with the safest design and traffic environment.

This was one of the main reasons for the extensive traffic management programmes of the City of Oslo and many other Scandinavian towns and cities inspired by the SCAFT principles for the design of road systems based on the principles of differentiation and segregation. In the period 1965 – 1985 numerous traffic management schemes were carried out in Scandinavia (and other countries) and several of them were also monitored by various types of research studies.

Figure 45 summarises some main results from Swedish urban areas, both residential districts and city centres.
Much more documentation is available (e.g. Elvik and Vaa 2006, Köln Stadt 1989) but this is sufficient to conclude that the idea of letting car traffic flow freely through almost all streets in an urban road network would lead to very serious reductions in urban traffic safety.

We can also add that very few of the citizens of our traffic-ridden cities are likely to accept any possible redesign of the urban traffic system that will return through traffic to their residential and shopping streets. In our opinion, urban traffic safety research since the 1970’s gives enough evidence to dismiss the idea of the homogeneous, open-ended grid network as a principle of urban planning and design for motor traffic.

**Combined use of several principles of safe road network design**

All experience indicates that a combination of separation and integration will give the best results with respect to reducing accidents and fatalities caused by traffic. A recent study carried out by the Swedish National Road and Transport Research Institute (VTI) is relevant for this discussion. It documents changes in accidents in the City of Gothenburg between 1990 and 2002, relating this to the different traffic plans that were implemented in this period and comparing the results with statistics from Malmö and Stockholm.

Gothenburg has had a strategy of persistent traffic separation, combined with traffic calming measures on streets that still have mixed use. The VTI report (2004) finds no difference in the number of accidents between Gothenburg and the comparing cities. However, the study observes significant reductions in the number of serious injury accidents as a result of the strategic separation and traffic-calming schemes in Gothenburg. The report concludes that the strategy of minimizing exposure and separating vulnerable road users from vehicular movements has been successful when measured by public safety goals.

A similar conclusion is drawn in the Dutch review of road safety (Wegman and Aarts (ed.) 2006) after an analysis of available research evidence on the principles of road system design. Their recommended ‘Sustainable Safety Principles’ is summarized in figure 46.

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**Figure 46. Five principles for the design of the road system for Sustainable Safety (Wegman and Aarts (ed.); 2006), table 1.3).**

<table>
<thead>
<tr>
<th>Sustainable Safety principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functionality of roads</strong></td>
<td>Monofunctionality of roads as either through roads, distributor roads, or access roads, in a hierarchically structured road network</td>
</tr>
<tr>
<td><strong>Homogeneity of mass and/or speed and direction</strong></td>
<td>Equality in speed, direction, and mass at medium and high speeds</td>
</tr>
<tr>
<td><strong>Predictability of road course and road user behaviour by a recognizable road design</strong></td>
<td>Road environment and road user behaviour that support road user expectations through consistency and continuity in road design</td>
</tr>
<tr>
<td><strong>Forgivingness of the environment and of road users</strong></td>
<td>Injury limitation through a forgiving road environment and anticipation of road user behaviour</td>
</tr>
<tr>
<td><strong>State awareness by the road user</strong></td>
<td>Ability to assess one’s task capability to handle the driving task</td>
</tr>
</tbody>
</table>
Traffic differentiation is a strategic noise abatement measure

In addition to the safety argument, traffic noise considerations confirm that traffic differentiation is a very useful tool for the improvement of the urban environment.

As indicated for some of the urban areas in figure 45, traffic management has normally given significant reductions in traffic noise exposure inside the environment areas. This is due to the effect of closing the street network for through traffic. Naturally, the largest effect is achieved when former through roads are converted to pedestrian streets, which has been the case in numerous European city centres during the last 40 years. Kolbenstvedt et al. (2000) show similar results from 6 Norwegian case studies of traffic management, and from the town centres of Gothenburg, Prague and Krakow.

Also the City of Cologne’s traffic calming programme in inner city residential areas reported significant improvements in the noise climate inside the environmental areas (Köln Stadt 1989).

Figure 47 illustrates the effect on traffic noise in an inner city area in the City of Oslo, where a traffic management programme was implemented during the 1970’s and the first half of the 1980’s. For the total area, including border streets with some increase in traffic volume due to the rerouting of traffic, the number of dwellings exposed to more than 35 dBA day equivalent indoor noise level, was reduced by 27 percent between 1974 (before) and 1984 (after). The same order of improvement (25-30 percent) was gained when measured as number of residents annoyed or sleep disturbed by traffic noise, or as proportion of pedestrian pavements with significant masking of speech between street users. The noise effect of the small increase in car traffic in border streets was offset by the improvements in vehicles noise emissions in the same 10-year period (Nielsen and Solberg 1985).

As an input to a national noise abatement programme, Nielsen and Solberg (1985) analysed the cost-effectiveness of different traffic noise abatement measures in various urban areas in Norway. Traffic management came out as one of the most efficient measures in that programme, especially when combined with noise screening and building insulation along the distributor roads. Traffic management (and improved noise characteristics of motor vehicles) can take away most serious traffic noise problems inside the environmental areas and significantly reduce the length of road and house facades needing noise protection. Then the cost-effectiveness of these measures also improves.

In later years noise researchers (e.g. Klæboe 2006) have focused more on the dose-response relations for dwellings with one noisy and one quiet side, and the protection of the urban acoustic environment by buildings that protect both their quiet side (with bedrooms) and outdoor recreation areas. Traffic management and road system differentiation assists in the provision of quiet areas in the city. This aspect may also be considered when the size of environmental areas, even car free areas, is discussed.
Local air quality improvements inside environmental areas

In some of the traffic management schemes already mentioned, also air quality measurements and/or exhaust emission calculations were made. In streets relieved of through traffic inside the environmental areas improvements in air quality have been reported, but not with so clear results as for traffic noise. This was due to background pollution levels, and possibly also different effects of the traffic calming measures introduced (see the earlier sections on speed reducing measures).

In city centres where the traffic management schemes usually include pedestrianisation of several streets into a car-free zone, quite significant air quality improvements have been reported in Gothenburg, Besancon, and Krakow (Kolbenstvedt et al. 2000, OECD 1979).

The total effect of traffic management schemes on traffic volume, energy use and air pollution at the city and regional level will depend on how the traffic management policy is linked to other transport and urban planning measures, and will at least partly be discussed in the next subchapter.
**Why the traditional grid is not the best solution for car traffic**

The results of research on traffic calming strongly indicate that the traditional open grid network for car traffic is not the best solution for the environment friendly, sustainable city. We will now go a little deeper into the question of network structure.

Traffic calming as a network strategy is advocated by Fehr & Peers Associates (no date). In a discussion they compare the cul-de-sac networks with the traditional open grid network, and argue that the traditional grid solution is to be recommended in comparison to the typical cul-de-sac network. They claim the benefits of the traditional grid network with full connectivity on all routes to be:

- 'Reduced arterial traffic volumes with more trips internal to neighbourhood
- Less need for ever-wider arterial streets
- Reduced traffic with higher level of walking and bicycling
- Lower speeds with reduced accident severity
- Lower vehicle miles of travel.'

![Typical Cul-de-sac](Typical%20Cul-de-sac%20Street%20Network%20Diagram.jpg)

In our view, their argument rests on (at least) three rather dubious presumptions:

1. That the total number of car journeys is given.
2. That the modal split remains unaffected by the accessibility for cars in the area.
3. That the negative environmental effects of car traffic are equally distributed along all streets in the area.

We believe all these assumptions are wrong in most urban situations, and therefore their argument in favour of the traditional grid network for car traffic is invalid. The two first points we will return to later in this main chapter. That the third presumption must be wrong is quite evident when one studies a real city.
Further arguments in favour of the cul-de-sac type of local road network are found in a Norwegian review of different types of traffic systems in housing areas. In Norway in the 1980’s, there was a strong argument between traffic planners, planning architects, property developers and housing associations about the appropriate design of new housing areas. Should the model of the segregated traffic system of the 1960’s and 1970’s continue as a blueprint for modern housing in greenfield developments, or should the local traffic system be designed for traffic integration with mixed pedestrian, cycle and car traffic on local access roads, with garages and car parking close to the entrances of dwellings.

Two research institutions (TØI and NIBR) made a review of relevant literature and facts concerning this question in Norway and Sweden (Kolbenstvedt and Strand 1986). Among other aspects they considered children’s use and safety of outdoor space in different housing areas, as well as the costs of infrastructure, and residents’ preferences in relation to different qualities of safety, environment and accessibility. They concluded that most of the factors considered were in favour of the segregated plan for such housing areas.

Compared with mixed traffic areas, car free housing areas and estates, with common car parking at the edges:

- are safer
- have cheaper infrastructure
- increase opportunity for social contact
- have limited problems of car driving on pedestrian paths
- have the most satisfied residents.

We will later come back to some house price value studies that seem to support the implication from this study that most residents seem to put a greater value on the environmental qualities of a relatively car free environment, than on the value of immediate access and short walking distance to their car when it is parked at their home.

Van Schagen (ed.; 2003) discusses three different network structures for residential areas, figure 49: the grid network, the limited access network, and the organic network. The areas are bordered by roads where the traffic function is given priority.
Figure 49. The three basic network structures of residential areas (Schagen (ed) 2003, from a study by Dijkstra in 1997).

Figure 50 summarizes the most relevant characteristics of the three network structures for residential areas.

It can be concluded that the organic network structure satisfies the traffic calming requirements most: ‘It is best in discouraging through-traffic and has the highest safety standard by nature. A point of concern is the central street of the network which has to carry a relative large amount of (destination) traffic and as such may easily turn into an internal barrier for its residents. Part of the solution can be found in increasing the number of non-motorized urban trips at the cost of the number of motorized urban trips.’ (Van Schagen (ed) 2003, p. 21).

![Table of characteristics for network structures]

Figure 50. Relative score of the three basic network structures of residential areas for the four most relevant indicators (van Schagen (ed.) 2003).

Further study by van Schagen (ed.; 2003) of the effects of the number of connections between the residential street network and the surrounding through roads showed that more connections result in:

- the distances travelled by residents is reduced, and
- the amount of through traffic is increased.

A further discussion of how one can encourage more journeys to be made by foot or on bicycle, stresses the desirability of short, direct and safe routes with as little disturbance from car traffic as possible.

None of the mentioned studies have analysed the network requirements of public transport and how the use of this mode may be encouraged. But
from other sources we know that a direct route through the middle of the catchment area is strongly to be recommended.

The design of the public transport route and its integration with the urban development can affect the cost of a public transport service in a residential area by a factor of up to 1:5, see figure 51.

This means, for instance, that a public transport oriented urban plan can offer an easily accessible, high quality service with, say a bus or tram departure every 10 minutes. For the same operating cost, a badly designed structure plan may offer a one-way ring service with longer walking distances, and longer bus travel time with only one or two departures per hour. It is easy to understand that all other things equal, the latter solution will generate more car traffic and make implementation of the sustainable city far more difficult.

Figure 51. Index of operational cost for different types of route layout in an urban area (Nielsen et al. 2005).

Figure 52 illustrates how transit-oriented traffic systems might be designed with a combination of direct rail and bus lines, car free stations, service centres and pedestrian links, and a separate road system for cars, including a park and ride site close to the main road network.
The importance of relative speed on arterial and local streets

Route choice of car drivers is an important aspect of traffic management, in particular the relative speed of travel on local residential streets compared to that of the arterial roads designed for through traffic. In many cities, a major concern in traffic policy is to avoid car traffic filtering off the main roads into residential and other sensitive roads and streets, in particular at rush hours with heavy congestion and delays on the arterials.

The Danish Roads Authorities have studied the ‘filtering’ of traffic on local roads due to congestion on major roads in rush traffic periods in the suburbs of Copenhagen (Vejdirektoratet 2000). They found that many local roads, not suited for through traffic, had significant extra volumes of car traffic in such periods. The proportion of ‘filtering’ traffic varied between 2 percent and 58 percent of the rush traffic (3 hours per day), and up to 22 percent when counted over a full day. The environment and social cost of this unwanted traffic on local roads was calculated to some 5.5 percent more than the rest of the traffic on the local roads. This confirms that there are significant benefits to be gained if through traffic can be kept onto the major distributor network in stead of filtering through on local roads.

A design guide for traffic calming in Devon County, UK argues that traffic calming through speed management can be used to discourage the ‘rat race’ without creating inconveniences for local access traffic, figure 53. By this one can obtain much of the same traffic rerouting effect of traffic management with street closures, one-way regulations etc., but still maintain free local access.
However, this effect will depend on the relative ease and speed of driving on the distributor roads and the local roads.

A study in Texas, USA suggests that there is a threshold effect when traffic speed is reduced on main roads because of congestion in rush traffic periods (Bonneson et al. 2000). When the speed on an arterial road drops below some 50 percent of the free-flow speed, a significant number of car drivers tend to seek alternative routes on local roads, if available.

Thus, when the rush period speed on main roads with a free-flow speed of 80 or 70 km/h drop down to 40 or 35 km/h, the drivers change to local roads (in typical US conditions) where the speed limit is some 50 km/h. By reducing local road speed to 30 km/h this result suggests that the problems of through traffic will almost disappear even when the main roads are rather heavily congested.

**A clear recommendation on network pattern**
The evidence presented in this subchapter leads us to the conclusion that the best solution for residential areas from the point of view of traffic safety and the objectives of the sustainable city is different for the different modes of transport:

- For motor vehicles, the organic type of network is recommended, see figure 49.
- For pedestrians and cyclists, the better accessibility of the grid network makes this the most attractive solution.
- For public transport, a short direct route in the middle of the catchment area is recommended, or two routes crossing each other where this is appropriate in a given regional public transport network.

This is very different from the traditional grid solution for all modes recommended by the advocates of new urbanism and other critics of conventional urban transport planning.
Traffic calmed residential areas should be as large as possible

Van Schagen refers to an interesting analysis by van Minnen (1999), who made an analysis of the effects of the size of the traffic calmed area on a number of variables used as indicators of road safety, liveability and accessibility for different modes of transport.

Van Minnen concluded that the size of residential areas should be as large as possible. Total car mileage is hardly influenced by the size of the residential area, and up to 200 hectares the size of the area does not have any effect on driving speeds. He also found that if the size exceeds 100 hectare, traffic volumes on the surrounding distributor roads will become a critical factor. If the size exceeds 200 hectare, traffic volumes on residential streets will become critical. Obviously, these conclusions will depend on the density of development, which is normally quite high in Dutch urban development. Also modal split will affect van Minnen’s recommendation.

He also concluded that the accessibility for pedestrians and cyclists is improved by making the traffic calmed area as large as possible, while car accessibility is slightly reduced. The accessibility for emergency response vehicles and public transport is a matter that should be monitored carefully.

Apparently, van Minnen does not consider the likely effects of traffic calming on mode choice and car trip generation.

Houten – a prototype that works in practice

The above conclusions about the type of optimal network and size of urban area that should be closed for through traffic by cars are confirmed when studying the results of the planned Dutch town of Houten outside the city of Utrecht.

In Houten, the transport network and town plan is designed to encourage cycling, walking and public transport use at the expense of car use. According to van Schaden (ed.; 2003) the combination of land use and transport network planning is a proven success.

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15 We have not had access to the original report by van Minnen, so we have not full insight into the analysis and have to rely on the description of results by van Schagen (ed).
Houten is a former village with some 4,000 inhabitants to a commuter town outside the city of Utrecht, with 28,000 inhabitants in the early 1990s. Houten is in fact one large residential area of approximately 300 hectare, divided into 16 neighbourhoods connected by a ring road. For cars there are no through-traffic opportunities from one neighbourhood to another, they have to use the ring road. Houten has a dense network of direct cycling routes and footpaths. At the time of surveys in the 1990’s, the inhabitants spent two thirds of all purchases in their town (100% in the food sector). Nearly all children go to school by bicycle or on foot. The use of cars in the town is 25% lower and the number of traffic-
injured people per 1000 inhabitants is less than 1/3 than in comparable towns (Jong and Bosch 1992, according to van Schaden (ed) 2003, and Meilof and Smith 1993).

**Much practical advice available concerning traffic calming measures**

We now have much evidence to support the idea of traffic calming in almost all of the urban road and street network. Many countries and regions have produced practical design guides that describe both the principles of traffic calming and how different measures should be located and designed to achieve the best possible results.

As an example, the following basic guidelines for the design of traffic calming measures have been pointed out in the Netherlands (van Schaden (ed.; 2003) 16:

- The speed reducing measures and devices should not distract the drivers too much, since this can make them overlook other important information in the traffic environment.

- The drivers should be able to recognise the measures and understand their meaning immediately. This will assist in making drivers accept the measures. Measures that look artificial and strange will not be easily accepted.

- To improve driver's acceptance, traffic calming measures should be placed in 'natural' places, such as pedestrian crossings.

- The traffic calming devices should be easily visible at all times. This can be realised by proper lighting or by using different colour patterns and reflecting strips. Shiny surfaces when wet should be avoided to prevent blinding by the reflection of sunlight.

In general, just a speed limit sign is insufficient to achieve the goal of 30 km/h on residential streets. Frequent discontinuities of alignment, width, and height, such as road narrowing, plateaus and humps; physically impose car drivers to reduce their speed. The use of different materials and colours help to break up the impression of a through-road for motorized traffic.

These types of measures not only aim to reduce driving speeds, but also make streets less attractive for through-traffic.

Speed reducing measures on distributor roads with an important traffic function should preferably be concentrated at locations where different road user groups have to mix, i.e. at intersections and midblock pedestrian or bicycle crossings.

At intersections, the application of roundabouts is a very effective way to reduce speed. In addition, at roundabouts the angle of impact is smaller, resulting in less severe consequences in the case of a collision.

As an alternative, plateaus can be used to reduce speed at intersections with or without with traffic lights. Plateaus can also be used to reduce speed at midblock pedestrians and/or bicycle crossings.

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16 The rest of this section is based on the text by van Schaden (ed; 2003), but slightly edited by the author of this report.
In the case of a series of intersections with traffic lights, a green wave may help to induce a constant speed at the stretches between intersections.

The transition from one speed zone to another needs special attention, in particular the transition from higher to lower speed zones, e.g. when entering a town, village or housing estate. A prominent gateway with high vertical elements alongside the road, such as trees in combination with a road narrowing, helps to bring about the desired speed reduction. Additional measures along the through-route within the built-up section are required to keep speeds at the desired level. In particular at through roads in villages this type of traffic calming schemes can be effective in terms of car speeds and traffic injuries.

In the design of traffic calming measures it has to be taken into account that distributor roads also have to accommodate for buses and trucks and should allow emergency vehicles to pass at a higher speed than other car traffic. Whereas some loss in comfort and time is unavoidable, the engineering measures can be designed and located so that the disadvantages are kept to a minimum. Examples are the use of plateaus rather than humps, and where humps are considered to be necessary; to use so called combi-humps or narrow speed cushions.

Bus stops should be located close to pedestrian plateau crossings, and may also be designed so as to slow down car traffic when buses stop for passengers (our addition).

The comfort and safety of cyclists in streets with many physical traffic calming measures can be enhanced by leaving space at both sides of the devices, so they can pass the devices in a straight line, both vertically as horizontally.

The design and location of traffic calming engineering measures must also take account of pedestrians, in particular those with visual and/or physical disabilities. Obstructions alongside or on the pavement should be avoided, as should large height differences and long distances at pedestrian crossings.

**Traffic calming and differentiation must include a combined strategy for the distributor roads**

The traffic management and calming schemes that have been implemented since the late 1960’s never lead to the serious traffic congestion and environmental problems on the border streets and distributor roads that the initially very strong opposition against these schemes claimed.

The main reason for this was the positive effect on car traffic capacity of the distributor streets that followed from the regulations of car traffic going in and out of the environmental areas, including the closing of some local streets at their connections to the border distributors. Car traffic movements on the distributors were simplified and this was sufficient to take the slightly increased traffic on the borders of the environmental areas.
In addition, the flexibility of route choice and travel patterns in an urban traffic network is so great that minor local restrictions on car flow is quite easily accommodated after a few days’ or weeks’ adjustment period.

Still, the existing distributors and most congested streets represent a very real problem which the sustainable city must deal with. They have a complex and rather intensive mix of street users, high accident risks and some of the most serious problems of local air pollution, traffic noise and other environmental disturbances of the whole city region.

Traffic calming of these distributor streets, often termed arterials when they are radial main routes through the inner city, can only reduce the environmental problems caused by car traffic to a certain level. To become a truly sustainable city environment, the volume of car traffic on these streets must be significantly reduced, as indicated by the quality criteria listed in the table of figure 31 earlier in this subchapter.

Furthermore, we have the sustainable city’s overriding need for reductions in the emissions of climate gases and in the use of energy for transport.

Therefore, the last topic of our analysis is the discussion of how to reduce car traffic in an urban region and the likely consequences of this for accessibility and the economic viability and social sustainability of the city.

4.3 The benefits and means of reducing and controlling car traffic

Accessibility for people and goods – not vehicles

To be sustainable in social and economic terms, all parts of the city region must have accessibility for people and goods transport. It is self-evident that the users of buildings and urban open space must be able to travel to and fro. In many cases also delivery or removal of goods is essential for the functions and activities taking place.

However, in discussions of urban transport policy and design it is quite common to implicitly interpret accessibility to mean access by motor vehicles, and the ease of driving by motor car and the amount of car parking spaces at the different destinations. When such a definition of accessibility is used, there is definitely a clear conflict between environmental quality and accessibility in the city. This leads to the common understanding that there is a trade-off between developing a sustainable city in the environmental protectionists’ meaning of sustainability, and the concern for the economic viability and the social sustainability of the city.

We will argue that the appropriate and most fruitful analysis of the possible conflicts between accessibility and environmental sustainability is to look upon the different modes of transport as means of providing access and transport. The analysis should focus on the objectives of giving people and goods accessibility to properties and places in the city, and not vehicles as such. By taking this approach one will discover that the conflicts between transport and environment are significantly less intense than commonly assumed.
The space requirements of cars reduces accessibility for other urban users

It is well known that that the private passenger car is very demanding of space when applied in an urban setting and compared with other means of access. As an illustration, figure 55 shows that the required road space for a typical urban journey by car may be 10 times that of a bus passenger, that a tram system may be even more space efficient, and still require more space per person than a pedestrian system. Figure 56 is a less formal illustration of the same point, which has been repeated in many cities.

Figure 55. Transport capacity for different modes of transport in a typical urban street. Upper part of the diagram: Persons per hour; for pedestrians only the side pavements are taken into the calculation. Lower part: Area (m²) per person. (Norheim and Stangeby 1995).

Figure 56. Illustration of the space requirements of a group of people coming to the town centre by car, bus or bicycle. (Nielsen et al. 2006; photo by the Ministry of Environment, Norway). As far as the bus system is concerned, we must remind the reader that in practice, buses seldom run at full capacity for more than some peak hour departures, and then only on short route sections.
These figures illustrate the point that in densely built-up urban areas, the highest level of accessibility, measured in numbers of people who can get access to a specific building or public space in a given time, can only be achieved if most of them come on foot, by bicycle and by public transport, and leave their cars (if they have one) parked outside the (inner) city. When large proportions of the available space in streets and urban places is devoted to car traffic, there will be less room and reduced capacity and quality for people using more space-efficient modes.

Here we have one of the simple explanations for the success of pedestrianisation, public transport priority measures and car traffic restrictions in city centres and shopping streets in many cities (see below): The schemes simply give access for more people to come in and use our city centres and urban areas. If well designed, they may also improve conditions for goods delivery, while the accessibility for car users is somewhat reduced in comparison with the traffic concepts that dominate the car-adapted city.

If one does not want to fill the city with car traffic and parking places, very heavy expenditure on infrastructure is a different possibility for the provision of car accessibility. But this alternative is so expensive to build and maintain that it has limited potential and applicability in most Nordic towns and urban areas, unless the public authorities want to heavily subsidise this type of urban development and transport solution.

In some parts of the largest cities, the objective of sustainable development may allow for some underground main roads and parking arrangements, but this should normally be seen as exceptions to the rule that most of the public funds available for urban transport should be devoted to the environment friendly and space-efficient modes of urban transport.

When large scale underground infrastructure for car traffic is in demand by some interest groups, one should seriously consider if underground public transport is a better alternative for the use of public money which is far more in accordance with the goals of the sustainable society.

**Significant environmental improvements on inner city distributors will require reduced capacity for car traffic**

Because of the rather inefficient use of street space dedicated for car traffic, it is possible to increase the capacity for persons and goods delivery in urban areas by rearranging street use for the benefit of public transport, cyclists, pedestrians and goods delivery vehicles.

This is especially the case for the congested inner city distributor streets that normally form a sort of backbone for both the urban public life and the public transport system of buses and/or trams. The point can be illustrated with an example from an urban street renewal plan on national route no. 4 in the inner city of Oslo, where redevelopment of a major traffic junction and urban square with adjacent streets is planned to begin in 2007, figure 57 and 58.
Figure 57. Junction between National road no. 4 and the urban ringroad 2 in Oslo inner city. Carl Berners plass (square) today, before the planned redevelopment of the space between buildings (2003-6). (Nielsen et al. 2006; photo: Rainer Stange).

Figure 58. Carl Berners plass (square) according to the plan for renewal, due to begin in 2007 (Nielsen et al. 2006; plan made for the National Public Roads Administration by Norconsult, Snøhetta et al.).
The main reason for this street renewal project is to improve the urban environment and the traffic conditions for pedestrians, cyclists and public transport. An important consequence of this priority of design objectives is that the peak hour capacity for car traffic in this important junction in the inner city’s car traffic system will be reduced by some 40 percent.

Nevertheless, the capacity for passenger traffic though this junction will be significantly increased. With less road space for car traffic, more space can be given over to buses and trams and their stopping places. The quality and efficiency of the traffic system for public transport passengers, pedestrians and cyclists will be improved, so that these modes will become a bit more competitive towards the car than before the redevelopment. Based on experience from similar projects in other cities greater use of public open space in the area may also be expected (see below).

This is an illustration of what will be needed in a city that wants to change its traffic system and transport policy away from the car based city towards the sustainable city: A combination of car traffic reduction and redesign of how we use the space between buildings: More space for people, less space for cars and all the traffic regulations and paraphernalia that comes with them.

**High social costs of traffic congestion**

The large space requirement of the motor car is perhaps the most important reason for developing an urban transport system that is less dominated by the car than today. As an implication of the private car’s lack of transport efficiency in dense urban traffic, all large cities and some of the smaller towns have significant problems of traffic congestion.

Numerous studies of the social costs of traffic congestion in urban areas have concluded that there are significant social benefits to be gained from reductions in traffic on congested streets. This is the main reason for the advocacy of road pricing as a key instrument in recommended urban transport strategies by many experts and policy commissions. We will comment upon the potential for traffic reduction later in this subchapter. But first some reference to early studies of the capacity of road systems for car traffic in towns and cities.

The connection between traffic volume and road capacity as observed in central parts of London in the 1960’s is shown in figure 59. The volume-speed function is likely to look a bit different under other urban traffic conditions. But the basic fact that traffic speeds fall rather rapidly when streets and roads become full of car traffic, is still valid. In the road systems of the 1960s most of the traffic management and road design effort was geared towards the improvement of car traffic flow. Today, the traffic engineering and control technology is more advanced, but now we have greater concern for public transport and traffic safety of pedestrians and cyclists. It is likely that the capacity restrictions on car traffic flow are stricter than 40 years ago.
In practice, when the traffic volume grows towards the capacity of the street, car traffic speeds do not go down to nil. Instead, a balance in the normal demand for car traffic occurs where the car drivers choose other alternatives than driving through the city at slow walking speed.

Based on empirical data from London and Paris, Mogridge (1990) argued that it is the speed of travel offered by the public transport system that defines the speed and volume of congested car traffic in urban areas. In our opinion it is more likely that the congestion level is influenced by the availability, quality and price of all behavioural options, including many public transport factors, cycling and walking, possibilities of changes in route choice and destination patterns, travel time and also effects on the total travel demand in the city.

We will return to the factors that influence the demand for car journeys later in this chapter. However, it is useful to look at a couple of studies that focused not so much on the behavioural aspects of the traffic system as on the pure physical restrictions of the road system and urban structure of cities.

This was the main topic of the case studies in the Buchanan report (Ministry of Transport 1963) that studied the consequences of the fast growing car ownership for road system design and the urban environment. Buchanan suggested a working method for the planning of urban transport where one defines the environmental capacity of streets and urban districts, and then study how the urban structure of roads and buildings might be adopted to cater for the amount of cars and traffic that was judged to be acceptable without destroying the towns’ character.

Some of the main conclusions were:
– For an ordinary English town of up to 30-40,000 inhabitants (Newbury) it seemed possible to cater for the car traffic generated by the ‘free’ use of cars at a level of car density of some 405 passenger cars per 1,000 inhabitants. But the costs of road building and car parking facilities needed to cater for this would be significantly higher than commonly accepted in England at that time.

– For a medium sized town with an historic city centre (Norwich with 160,000 inhabitants) strong restrictions on car traffic were needed to protect the character of the city. An approximately 2 km² zone within a city ring road should be almost closed to car traffic, and a number of parking houses had to be built close to the ring road. Even this concept of restrictive car use and urban redevelopment seemed very difficult to combine with the protection of the cultural heritage and character of the town.

– In a larger city (such as Leeds), the building of an extensive motorway system of 85 kilometres, in addition to traffic protected environmental areas between distributor roads, the car traffic could not cater for more than 26 percent of the journeys to work in the city centre.

Smeed (1968) also studied the shape and capacity of the road network in English towns, and estimated how the journey times for travel to work by car was likely to be affected by the modal split of commuters. He estimated that in a city centre with some 100,000 commuters, the speed of car traffic would become very slow as soon as more than 30 percent of the journeys to work would go by car.

Obviously, the road system capacity will depend on the number of roads available and the quality and capacity of each of them, as well as the flexibility of the road network for car drivers who want to change route when congestion starts to build up on their primary choice of road. Many Norwegian and Swedish cities have a difficult topography for road building and urban development. This, in addition to the more common wishes to protect land, nature and residential and historic areas, create a more limited road system for heavy car traffic than in many British or Continental cities on flat building land and with many roads leading into the inner city from the surrounding region.

This hypothesis seemed to be confirmed in an analysis of changes in car traffic volumes in the 15 largest towns in Denmark, Finland, Norway and Sweden in the period 1975 – 1988 (Nielsen 1992). It was shown that in the city centres of the largest cities (above some 300,000 inhabitants) car traffic growth had already stagnated, while there still was very strong growth in car traffic in the suburbs of the same cities, and in the smaller towns. The inner cities’ car traffic and parking systems has for many years been operating at the level of capacity restraint that the market for car use leads to in these areas.

Calculations of the social costs of car use have shown that a significant reduction in peak period car traffic will be profitable when one operate the system close to full capacity.

17 In Sweden and Norway this level of car ownership was reached by the year 2000. According to the Statistical yearbook of Norway the number of passenger cars per 1,000 inhabitants in 2001 was 400 in Norway and 426 in Sweden.
Figure 60 gives an example from Jansson (1995) of the very steep increase in the marginal congestion costs that occurs when car traffic grows towards the capacity of a road or street. Figures such as these are good reasons for why car traffic should be reduced at peak periods in congested urban networks, in particular in inner city streets.

However, Jansson (1995) also estimated the marginal accident costs in streets with very few vehicles and many pedestrians and cyclists in or crossing the street. The results in the two right columns in figure 60 shows that it is a good idea to take car traffic completely out of streets with very few cars if there are many pedestrians and/or cyclists that can be hit in traffic accidents. In this calculation only real accident risk is considered. Putting a value on the feeling of traffic safety would result in higher social cost of accident than indicated in figure 60.

So here we have arguments both for a reduction in car traffic at high levels of road capacity use, and for the differentiation of car traffic and segregation of pedestrians and cyclists so as to minimize conflicts between cars and unprotected road users.

**Environmental reasons for traffic reduction**

In addition to the transport efficiency reasons, there are a number of environmental reasons for the sustainable city region to significantly reduce the volume of car traffic.

The need to reduce emissions, traffic injuries and fatalities and the use of energy for transport, clearly requires a switch of travel modes from the car towards walking, cycling and public transport. Figure 61 is a succinct
presentation of some of the major factors, in particular those related to global sustainability and the life and well-being of people that live in cities and other urbanized areas.

In addition, one should recognize that urban structures and transport systems that are designed to accommodate high levels of car use, 'will to some extent reduce the ability of the urban structure to support both the patronage and quality of public transport, and the possibilities for journeys to be made on foot or by bicycle.' (Pharoah and Apel 1995, p. 6-7).

Figure 61. Comparison of urban transport modes in relation to emissions (NO\textsubscript{x}), energy use, noise, traffic fatalities and space requirements in relation to the passenger transport capacity (person-kilometres or persons travelling). Index, tram = 1.0. (Pharoah and Apel 1995/DIFU).

PKM = Per person kilometre, PT = Per person travelling
Index: Tram = 1
New technology cannot solve all the problems of car use in the sustainable city

Quite often it is argued that improvements in motor, fuel and car technology will take away or significantly reduce the need for reductions in car use and motor traffic volumes in urban areas. Certainly we should exploit the possibilities of new technology, but at the same time we must take account of the limitations:

- Much of the car traffic problems in urban areas are only marginally connected to technology. The use of restricted urban space and the contributions of human factors to traffic safety and behaviour and use of technology are in this problem category. People driving faster with better braking systems and buying larger cars when the motor demands less fuel per km driven, are examples of challenges not so easily solved by new technology.

- It takes decades to change from an existing, petroleum-based fuel and technology system to a new technology, yet unproved in the real world of competition, market mechanisms, wear and tear, etc.

- Most of the new technologies have some rather critical disadvantages that have to be dealt with before they are taken into the mainstream of ordinary transport systems in daily and long-term use.

Further, it is not necessarily so that all new technologies that contribute to less local pollution also can be seen as a significant contribution to a more sustainable development on a global scale. Høyer and Holden (2005) have analyzed the likely ecological footprint of a number of fuels and passenger car propulsion technologies. By doing this, they take into the calculation not only the use of energy and the emissions when the car is in use. They look at the whole energy chain of the production of the fuel and the full life cycles of both the car and the infrastructure used by cars. This perspective is often called a well-to-wheel analysis.

As a common measure for all the different types of ecological impact of this process, they calculate the land area needed to produce a car trip with the different technology chains and to assimilate the materials used and thrown away afterwards. By this it becomes possible to use a single accounting figure to compare the different technologies’ impact on global sustainability.

Numerous data about the different technologies and stages in the production process were taken from a large number of international research studies. A strong attempt was made to reflect the state of knowledge and technological development by only considering serious sources published in the year 2000 or later.

The main results of their analysis for 18 of the most relevant technologies that may be – at least in theory – at hand for Norway in 2010, is shown in figure 62. Separate diagrams for each of the components energy use, emissions of greenhouse gases and NOx emissions are presented in a second paper (Høyer and Holden (in print)).
Høyer and Holden found that better use of existing technology can make a significant contribution towards the reduction of the ecological impact of car use. As much as 22 percent reduction of the ecological footprint can be achieved for petrol cars and more than 35 percent for diesel-fuelled cars. Further, natural gas energy chains may imply 45 – 75 percent reduction in the ecological footprint. However, as these technologies rely on non-renewable resources, they do not fulfil the long term requirements of a sustainable energy system.

Hydropower energy chains – one of them with hydrogen fuel cell cars – may imply reductions of 75 percent in ecological footprint compared to a reference fossil fuel car. ‘But this is not a global resource with sufficient volumes to support the large and ever increasing transport systems’ 

…..Renewable alternatives based on extensive biomass resources may on the other hand lead to substantial increases in ecological footprints, which is the opposite of an environmentally friendly option (Høyer and Holden 2005, p. 13).

From this analysis Høyer and Holden conclude that sustainable mobility cannot be achieved by technological means only. In addition we need both substitution of car use with public transport, walking and cycling, and a reduction in the total volume of travel.

We can add that these policy tasks for the rich urban regions become even more important in a national and global perspective: Unlike rural districts, urban regions have many and attractive policy options as far as the reduction of car use is concerned. As shown elsewhere in this report, a number of local and regional benefits can be gained at the same time as
the cities and urban regions contribute more towards national and global sustainability.

Further, the rising tide of increased motorised transport in the poorer countries with the majority of the global population will necessarily create a very strong pressure on the global resources and environment. Also other sectors of the economy will need more energy and create additional burdens on the Globe. Using arable land for the growing of biomass for fuel production in stead of producing cheaper food for the hungry seems to be rather evident ethical and political conflict. Giving up uneconomical car use that disturbs urban life and destroys the character of cities and urban places, is no great sacrifice to the future sustainability of the planet. It is simply common sense.

To underline this point we will now briefly refer to some studies of how the volume of traffic in urban streets and roads affects both the residential qualities of the city, and the vitality of shopping and urban life.

**Attractive housing requires low traffic volume**

In the former subchapter we demonstrated that the negative environmental effects of motor traffic are clearly related to the speed of traffic. The volume of motor traffic on the streets and roads of the urban area is equally or even more important.

Surveys in Norwegian urban areas (as elsewhere) show clearly that motor traffic outside houses and flats must be kept at rather low volumes when the objective is to have high or medium residential environmental quality in our cities. We can ad that this is not only a question of residential quality. High quality environment is an important factor for the attractiveness of the whole city, and this is crucial for the city’s ability to attract the well educated population that is needed to secure the region’s future economy.

Figure 63 shows the percentages of the population in urban districts in the inner city of Oslo and in the towns of Drammen and Horten who state that they are bothered by noise or pollution, and the correlation with traffic volumes in the streets outside their dwellings (flats). There is a linear relationship from very little car traffic up to some 25 – 30 000 vehicles per day. At this level, 90 percent of the residents state that they are bothered by noise or pollution from traffic. At low volumes of traffic more people are annoyed by air pollution than traffic noise. This is due to the high background pollution levels caused by the total traffic in the city, and other sources of air pollution.

The surveys showed a clear effect of car traffic on daily residential life and well-being (Transportøkonomisk institutt 1991). According to the residents, increased traffic in the streets where people live results in:

- More disturbance of listening to radio and TV
- More dirty windows, curtains and cupboards
- More uncomfortable to open windows for fresh air
- Less use of open windows to improve indoor air quality
- More disturbance of rest at home
Less use of open space in the area they live.

This survey indicates that there is little help in the numbers as to find an exact limit for environmental capacity in relation to traffic volumes. The acceptable amount of bothered residents is a matter of judgement. The natural objective must simply be to keep traffic volumes as low as possible when designing streets and roads in or close to residential areas.

Figure 63: An extensive research programme on the environmental effects of car traffic in the urban district of Old Oslo in the inner city of Oslo, and in other areas, has made it possible to describe the effects of traffic and traffic related noise and air pollution on the residents' well being, health and how their use of their dwellings is affected by the traffic nuisances. This diagram describes the relation between car traffic volume and annoyance from traffic noise (the white curve), air pollution (black) and either noise or air pollution from traffic (blue). Traffic volume in 1000 vehicles per day in the street outside dwellings. (Transportøkonomisk institutt 1991).

It is worth noting that the level of annoyance with traffic noise was seen to be higher when the residents were also exposed to high levels of air pollution. Sometimes it has been suggested that the noise and pollution objectives should be somewhat more relaxed in urban areas, because people living in such areas get used to higher levels of noise and pollution. The studies in Norwegian towns indicate the opposite conclusion: People in the cities who have this type of double exposure to traffic nuisance, require stricter noise and pollution standards than in areas only exposed to one of the factors of traffic emissions.

The surveys in the Norwegian cities confirmed the existence of a barrier effect due to heavy car traffic in residential streets. This effect is felt among residents living at several hundred meters from the through route with heavy traffic. This confirms the conclusion in subchapter 4.2 that environmental areas without through traffic should be as large as possible.

A study of children’s' road to schools in the Danish city of Aalborg showed that the barrier effect increases fast with the traffic volume, figure 64. At some 3 - 4 000 vehicles per day in more than 50 percent of the time the children were unable to cross the street on their way to and from school. At 8 – 10 000 vehicles per day only a small proportion of
the time was free for such crossings. These figures confirm the idea that only low volumes of (slow) car traffic should be allowed on streets that school children have to cross for their daily, and obligatory, trips to and from school.

Figure 64. Percentage of the time school children were unable to cross the road at different volumes of car traffic. School route crossings of seven roads in Aalborg with a speed limit of 50 km/h (Nordic Council of Ministers 1978).

However, the barrier effect of car traffic through residential areas is not restricted to children. A classical study by Appleyard et al. (1976) illustrated how traffic annoyance increases and social contacts with neighbours decreases at higher volumes of car traffic, figure 65.

The reactions of residents to car traffic in the streets where they lived include the following (from the report abstract):

- Heavy traffic caused many people to move away from a street.
- People who remained on a street with heavy traffic adapted through withdrawal from their yards and even from the fronts of their houses.
- Even on lightly travelled streets traffic safety was seen as a problem, but it was the occasional fast car rather than the continual traffic.
- Lightly travelled streets were occupied by more families, owners and long-term residents than more heavily travelled streets.
Positive economic and social effects of improvements of the traffic environment of housing areas

It is a quite common experience that improvements in traffic environment has the opposite effect on people’s attitudes to their housing areas and their willingness to stay there and invest in improvements.

In UK, the Department for Transport (2005) has summarized results from studies of the effects of a number of ‘Home zone’ projects of traffic calming in local residential streets. Significant speed reductions are reported; over half of the schemes reported achieved speed reductions between 10 and 15 miles per hour. All zones reported an improvement in
the environment through the use of premium materials, planting of street trees etc.

The projects also act as a catalyst for small scale renewal of properties: 'House owners are taking more pride in their area and are carrying out external refurbishment of their properties. ... Many schemes have reported reductions in the turnover of tenancies and the number of empty properties.' (p. 84).

Many zones reported that the schemes have raised morale and community spirit. There are indications that crime has been reduced, in some areas very impressive statistics has been presented. Improved street lighting has enhanced feelings of personal security. A number of zones also reported that housing prices have increased as a result of the street measures, and estate agents often use the schemes as marketing features.

These conclusions are similar to the results of much older traffic environment improvements in residential areas in Oslo and Trondheim in the 1970s (Statens vegvesen 1983). Traffic management and traffic calming has been seen as a prerequisite for renewal and new development in inner city areas run down by car traffic (Kolbenstvedt et al. 2000, p.258).

**Housing prices reflect people’s preferences for environmental qualities**

For a number of years Norway has had a rather deregulated housing market, so peoples’ quality and location preferences are reflected in the prices people are paying when they move to a new (used or unused) home. A few multivariate studies throw some light on the urban populations’ preferences in relation to environmental quality and accessibility.\(^ {18} \)

Medby (2001) has reported an empirical analysis of the prices for owner-occupied dwellings in Norway in the period 1991 – 2000. As in many other studies, prices of houses and flats were higher in centrally located areas than in the outskirts of towns and in rural districts. This was particularly the case for houses. For large flats (for families) the effect of centrality was weaker than for houses and small flats.

Comparisons between Oslo and Trondheim indicated that the light rail system in Oslo (‘T-banen’) positively affects prices of flats in the suburbs. The availability of a garage for the car(s) had a positive effect on prices, but not so much in Oslo as in other towns, possibly due to a better public transport system. The effect of garage was weakest for small apartments in Oslo.

A study by Larsen et al. (1997) was more specifically designed to assess the impact of traffic noise and other variables on market prices of housing properties. Two sets of data were used; cooperative housing apartments sold in Oslo in 1995, and owner-occupied houses in Oslo sold twice or several times in the period 1988 – 1995. The main conclusions were:

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\(^ {18} \) The studies included variables such as type of dwelling and ownership, size and age, sanitary standards, etc. in addition to the variables concerning environmental qualities and accessibility by car and public transport that we are interested in.
– Prices for owner-occupied houses decreases by 0.54 percent for every dBA
  increase in estimated traffic noise at the building facades.
– For apartments in co-operative housing the effect of traffic noise was
  approximately 0.25 percent per dBA.
– The difference in effect might be due to other traffic related factors
  (pollution, traffic risks, barriers, etc.) that might be less important in the co-
  operative housing, which are more in post-war planned housing estates with
  public open space screened from car traffic.
– The quality of public transport provision affected prices, in particular for
  the co-operative apartments.
– Prices were higher for dwellings near the city centre than those further out
  from the centre.
– There are certain areas with different status levels the specifically affect
  prices of houses and apartments.
– The effect of traffic noise and other traffic disturbances was seen as
  consistent with findings in earlier Norwegian and foreign studies.

Larsen et al (1997) made an illustrative calculation of the value of 50
% reduction in car traffic in residential streets (resulting in 3 dBA
noise reduction). The marginal environment cost of car traffic on
residential property – as an average for all motor traffic in Oslo - was
estimated to NOK 0.09 per vehicle-kilometre (1997-prices).

The studies of house prices document that there are social economic
benefits to be gained in the housing sector from an urban transport policy
that reduces car traffic, in particular in residential areas where many
people live, and that improves the quality and accessibility of public
transport.

A similar picture of people’s preferences when they plan the location and
quality of their new dwellings was revealed in a market study for a large
housing development on the edge of the inner city in Oslo (Bjørneng and
Elnan 2004). Size and type of dwelling, and a location in particular parts
of the city are the first considerations. Then follows central location,
public transport and the quality of green, recreational areas and closeness
to nature. Local services, schools and kindergartens are also important.
Few were concerned about car accessibility, provision of car parking etc.

This does not mean that the latter qualities can be neglected; only that
environment quality, public transport and other services are more
important for the future design of residential areas in the city of Oslo.

**What about car traffic and business activities?**

One of the more debated issues of traffic calming and car traffic
regulation is related to the effects on business, and in particular retail,
which depends so much on visibility and accessibility for customers.

A vibrant and healthy retail and service industry is essential to any city
with ambitions to survive economically and to have a lively city life in
streets and public places. Naturally the care-based city has conflicts
between the demand to provide accessibility to the specific retail location
from a sufficient geographical area, and the need to create a people friendly environment around and at each location.

In retail, as in all real estate, location is everything. But what constitutes a good location for a certain business depends highly on the nature of the business, i.e. turnover, the type and size of goods: can they be carried in a small bag (clothes, shoes, small amounts of food), or must they be transported (furniture, weekly grocery shopping), perishables versus non-perishables, etc.

The traffic system affects the status of a certain location through the accessibility it provides and by the nature and amount of traffic. The latter contribute to the character of the street and both factors influence how the street attracts certain businesses and not others.

A street that is planned with the emphasis on pedestrians will provide great locations for stores that cater to wandering shoppers, such as stores for clothes, shoes, accessories and gifts. These streets will naturally also provide great locations for restaurants and cafés and, as a whole, provide customers with the leisure and pleasure of urban life. However, the assumption is that the street is accessible for a large number of people and potential customers.

If the larger part of an urban area is densely planned, there might be a sufficient market in the local neighbourhood as a whole. Moreover, the dense city can provide for good public transport systems, which can give people from further away access to the shopping and restaurant streets.

However, if the city as a whole is sprawling and/or the public transport system is underdeveloped, it is necessary to give access to shopping and recreational activities by way of car traffic. But problems occur when through traffic in some streets or neighbourhoods becomes too heavy and creates problems for businesses located along that street. When this happens, these businesses are likely to move out of this neighbourhood, to areas where accessibility is better and the problems less profound.

**More people and better shopping with less car traffic**

In contrast to what is often claimed, positive effects from car traffic reductions and environmental improvements can be gained for economic activities such as retail businesses, restaurants and other typical urban personal services. This has been seen in a large number of cities and empirical studies, as reviewed by the author (Nielsen 1997).

Studies of the citizens’ attitudes, preferences and increasing use of urban public spaces show that they highly appreciate the environmental qualities of the city and town centres, and that these qualities are more important for the use of the centres than the ease of access by car. The continuously growth of pedestrian and traffic calmed areas in the cities give clear evidence of this.

This is due to the fact, already commented upon, that car accessibility is too space-demanding to allow for the concentrations of visitors and customers that are needed for a dense and vital urban centre to function properly. These centres depend strongly on the accessibility provided by public transport, walking and cycling. They are likely to benefit even
more from a transport policy with less car traffic and further quality improvements of the environment and the other means of transport.

Even the suburban and out-of-town shopping centres are based on the concept of car free shopping streets, and recreational and cultural functions are becoming part of the centres’ strategy to attract more customers. This demonstrates the importance of the environmental and service qualities for retail and service businesses.

However, to a very large extent shopping outside the urban centres is based on accessibility by car. Therefore huge areas of car parking are needed outside the pedestrian, indoor shopping malls and the more conventional shops. In many cases the area occupied for car parking is significantly larger than the floor area needed for the sale and storage of the goods. Often walking distances between shops and parked cars are of the same order of magnitude as in many car-free city centres – and go through a far less attractive and comfortable environment.

In the sustainable city, this type of urban development is likely to be seen as an undesirable use of resources, and a change of transport and planning policy will be required. Some of the most car-dependent and traffic generating facilities will probably have to be transformed to other functions in order to create a more sustainable urban structure.

The shopping centres and facilities of the highest quality and the best locations are likely to survive and flourish also in an urban region that is less dependent on car use than to-day. By intensifying land use close to the centres with apartments and work places – partly on land now used for car parking only – more customers will be able to walk or cycle to the centres. And by developing the public transport system also regional accessibility to the centres will be secured even at a lower level of car use than to-day.

These changes will have to be stimulated through a combination of urban planning, investments in environmental friendly transport, traffic management, car parking restrictions and higher costs of car use.

A British review of the effects of traffic restraint on retail vitality has confirmed that much car traffic in shopping streets affects businesses negatively, and that restrictions on car traffic often stimulate shopping turnover (Sustrans 2006). A study of six Midland towns showed that the supply of car parking did not affect the rate of shop closures, and that the environmental qualities of town centres was very important for the amount of shopping business.

A similar lack of correlation between retail turnover and parking provision in city centres has been found in German cities, figure 66.

Further, a study of empty shops in the English city of Leicester found that the percentage of vacancies increased with the volume of car traffic in the streets, figure 67.
Figure 66. Retail turnover and car parking provision in German city centres. Vertical scale: Low level of parking provision at the top. Horizontal scale: Retail turnover, Dm per m² of retail floor space. (Test 1988; diagram from Norheim and Stangeby 1995).

Figure 67. Percentage of vacant shops in Leicester as a function of the amount of car traffic in the street (Sustrans 2006).
The following conclusions from the Sustrans (2006) study are relevant for the design of the traffic system and policy of the sustainable city:

– 'Retail vitality depends in large measure on an attractive environment.
– Heavy and/or fast-moving traffic drives people away.
– Traffic restraint should always be combined with measures to improve the street environment, such as pavement widening, seats, planting, decorative surfaces, raised pavement crossings, improved cleaning and maintenance regime.
– Successful trading streets offer wider choice than a Mall, with a wide mix of retail and other uses, such as cafes.
– Most shoppers come on foot, by bus and by bike.
– Easy car access is less important than many traders think.
– Bus access is important, and stops may need to be moved to best suit the needs of customers.
– Pedestrian routes to shopping streets must be good, with clear signing and priority over motor traffic.
– Cycle parking needs to be “little and often” and very close to popular retail destinations.
– It is worth losing some car parking slots to create an attractive streetscape.’

These conclusions are in line with recommendations for town centre development by the Norwegian Ministry of Environment (Miljøverndepartementet 2000). It is also worth noting that the British Chamber of Commerce concluded in a review of strategies for town centre prosperity that ‘the ideal solution to deal with the conflict between car use and the commercial success of a town centre is a well run public transport system with managed car access’ (BCC 1998, p. 19).

We can conclude that even customer oriented and accessibility-dependent urban functions as (much of) the retail business will benefit from the same type of transport policy as desirable for residential areas. City centres and many other shopping areas will gain from environmental improvements created by reductions in car traffic and the increased provision of public transport, pedestrian and cycling facilities.

**How can car traffic volumes and transport demand be controlled?**

Finally in our analysis, we must say something about the practical possibilities for car traffic reduction and control of car traffic volumes in particular streets or larger areas of the city.

This is a huge topic in itself, so space will only allow for some references which serve as a basis for our final recommendations. The interplay between transport quality, land use and accessibility, and the effects of these factors on travel behaviour and the amount of motor traffic, is a large field of research that is impossible to cover in this study. However, in order to enlighten the debate about the form of transport network and urban design that is most appropriate for the sustainable city, we will briefly present some evidence on these relations.
First we look at the connections between road capacity and car travel demand. Then we deal with the evidence of how car traffic may be affected by public transport provision and also whether measures that promote cycling and walking have an effect on car use. Finally we refer to the experiences gained from car restrictive policies such as traffic calming and management, parking regulations, user charges and road pricing.

**New road capacity is often counter-productive**

An empirical version of the classical relation between traffic volume and speed was shown in figure 59. When traffic volumes on a road goes up, the average speed of travel goes down.

Common sense and market theory tell us that there should be a close connection between the demand for car traffic and the supply of roads. It seems obvious that the capacity and quality of roads and traffic regulations have an impact on the amount of car traffic generated. But for political reasons this fact has taken several decades to come into the mainstream of practical transport policy in many countries. In our opinion, the discussion and research should now concentrate on gaining more understanding of the quantitative relations between car traffic demand and different variables, including several factors that are open to public control and political decisions.

At the beginning of the 1990s, Nielsen (1992) made a summary of the international literature on the effects of transport investments on transport demand and other factors, including case studies of many new road projects in Scandinavia, Europe, USA, Australia and New Zealand, and several impact studies of public transport projects. Both theoretical analyses and empirical evidence was looked at. Without going into the complex details of how the various results had been reached at, he concluded that the expected effects of transport supply and travel demand were documented in real world situations.

Later and more thorough international (OECD and ECMT 1995) and British (SACTRA 1994 and Cairns, Hass-Klau and Goodwin 1998) studies came to similar conclusions. In Norway, later studies of transport and land use developments in the urban regions of Oslo and Bergen have confirmed the interaction between road building, urban development and transport demand (Foslie and Lian, 1997 and 1999).

From these sources the following conclusions may be drawn about how the building of new roads influences car traffic demand in urban areas:

- The effects of new road projects on car traffic depend on the local situation, the level of congestion and amount of ‘suppressed’ demand, the quality of available transport alternatives, the type of road network in the area, etc.
- During the first months after the opening of a new major road link, a clear improvement in traffic flow usually takes place, and this is often the main reason for building the road. Many drivers change their choice of route, and some existing, parallel roads are relieved of traffic.
- Sometimes the traffic flow on the new road might create new bottlenecks at other road sections or junctions in the road network, so that the journey
time of cars is increased, and not reduced as was the intention (‘Braess’ paradox; Braess 1968).

– After some 1-3 years, an extra volume of car traffic is likely to have been induced by the new road project. This has been documented both for completely new road links and for an increase in the capacity of an existing road.

– In the longer term, the new roads often induce new patterns of land use and stimulate longer journeys by car after relocations of households, activities and businesses.

– The new roads normally increase the travel time advantages of cars in relation to journeys by public transport, which induces people to switch from public transport to car use. This reduces the patronage and income of the public transport system.

– Often congestion on the new and old roads limit – and often eliminate entirely - the travel time improvements for car travel in peak hours, while significant improvements in car speeds are achieved at other times. This creates greater variations in public transport demand over the day, which further undermine the operational economy of the public transport system.

– Data from a number of Nordic towns show that the potential demand for even more car traffic is very big under existing conditions in the transport system. Much of this demand is now suppressed by lack of road and parking capacity, and would be realized if more capacity for car traffic is provided.

These mechanisms in the urban transport market leads to the conclusion that – at least in large and medium sized towns – new road building often is part of the problem of urban traffic congestion and environment disturbance, and not the solution that many road traffic planners and decision makers still tend to believe.

The following conclusion from the OECD expert review has not yet reached all decision-makers in the field of urban planning and transport policy:

‘Building more and more roads in cities and conurbations has enabled more people to travel by car, but has not reduced peak-period congestion to any noticeable extent. As soon as new road space becomes available in large cities, it is quickly filled. Even city regions with the most extensive road networks have high congestion levels. Attempts to solve the congestion problem in this way, especially in Europe, would change cities beyond recognition, the cost would be prohibitive and congestion would still not be eliminated.’ (OECD and ECMT 1995).

Here we must ad that for the sustainable city, a continuation of the road building programmes of the last decades would be entirely counter-productive and a waste of resources, except for some road investment projects that might solve specific, local environmental problems, facilitate some new urban development or be part of a comprehensive improvement package to change modal split and reduce the burden of car transport on the city and the environment.
**Reduce road capacity — get less traffic, and no extra congestion**

Cairns, Hass-Klau and Goodwin (1998) examined closely the theoretical considerations and the empirical evidence on the effects of highway capacity *reduction* in a large number of cases in many cities and countries (some 150 sources from over 100 places).

Their conclusions concerning the effects of reductions in highway capacity in urban areas are as follows:

- The effects of a particular capacity reduction will be substantially influenced by the circumstances of the case.
- When the capacity reduction of a highway is offset by improvements on alternative routes, no change in overall traffic levels or congestion occurred.
- When there is sufficient spare capacity on alternative routes to take the traffic diverted from the highway with capacity reduction, very small changes in total traffic volume take place. But congestion spreads out over time and space.
- When highway capacity is significantly reduced, and there is not adequate capacity on alternative routes or at alternative times, then a proportion of car traffic ‘disappears’ and other car drivers reroute or retime their journeys.
- The (unweighted) average change of car traffic volume in the affected area (including traffic growth on alternative routes) of all cases was some 25 percent traffic reduction in relation to the roads treated by closure or capacity reduction.
- People’s responses to capacity reductions are similar to their responses to capacity increases, but they may not necessarily be symmetrical, especially in the short term.
- Car drivers used a wide range of behavioural changes in response to the road capacity reductions, and the aggregate result on traffic flow on the directly affected routes occurred as a combination of the same drivers changing their behaviour and a change in the group of drivers choosing this route.
- The long term effects depend on other changes and policy measures. Sometimes the effects of traffic reduction are only temporary, but when supported by other measures (e.g. improved public transport) the long term effect can be bigger than the effects shortly after the capacity reduction was introduced.

This brings us over to the documented effects on traffic flow and congestion of more local street capacity reductions and traffic calming.

Cairns, Hass-Klau and Goodwin (1998) compared two set of town-scale cases, with very different effects on car traffic demand and the urban environment:

- Bypass highways constructed at the outskirts of six British towns induced more extra traffic than any reductions brought about by capacity reductions in the town centres they relieved. Some 20 percent traffic growth was attributed to the schemes.
In several German cities there have been much more ambitious reallocations of capacity, with pedestrian areas covering most of the traditional town centre, bus priority, cycle lanes and traffic calming constituting a long term strategy. In cities like Lüneburg, Freiburg, Nürnberg and Munich the measures have not only changed modal split away from the car, but has also created highly successful, environment friendly and popular city centres.

Nielsen (1992) compiled an overview of the effects on travel and modal split of traffic management and transport policy measures that were carried out in 16 different European town centres and inner city districts in the period 1970 – 82, figure 68. The diagram shows that significant changes in modal split and car traffic were achieved. However, in most of these cases, the possible reductions in capacity for car traffic were more a result of the priorities given to other road users, so these changes in modal split were a result of a combined ‘push and pull’ strategy.

Other traffic calming schemes have also achieved some reductions in car traffic, but this too has been more of a side-effect than a clear objective of the measures. They aimed at reducing speed and, in some cases, encourage or force drivers to take a different route with less negative effects on traffic safety and the local environment.

We have already mentioned that Bonneson et al. (2000) reported between 5 and 25 percent reductions in the volume of car traffic due to traffic

Figure 68. Changes in modal split for journeys to 16 city centres where a number of measures to restrict and reroute car traffic were combined with various other measures, such as improved public transport, cycle facilities, pedestrian areas and parking restrictions (different packages of measures in each city). To the left: percentage car traffic reduction. To the right: percent increase in public transport (white bar) and walking/cycling (grey). (Nielsen 1992, data from various sources).
calming devices on residential streets and roads, see figure 35. The largest value may be found when alternative routes exist, but 5-10 percent reduction in car traffic has been achieved when there are no alternative routes than the traffic calmed road. Even bigger reductions in traffic volume have been reported for traffic calming projects on main roads through villages in several countries (Haddeland and Nielsen 1992).

Some 3 percent reduction in traffic volume was measured as a result of an speed limit reduction from 80 to 60 km/h on highway no. 4 in Oslo (Statens vegvesen 2005), but it is likely that most of this small change was due to rerouting.

Much larger changes in traffic volumes are achieved by stricter traffic management schemes that include the closing of streets to car traffic, one-way regulations etc, see figure 45. In some of these projects, and also in other traffic management programmes, it has been reported that some of the car traffic ‘disappeared’ as a result of the traffic regulations. But the studies normally only looked at traffic inside the protected areas and the border distributors, and seldom considered the total traffic volume of the whole city or town.

Last in this discussion of restrictions in the car traffic system, we will mention the possibility of using existing technology to discriminate between different road users and their vehicles. This opens for a more differentiated policy of traffic regulation, figure 69.

![Figure 69. Using the same technology as in many private car parks, the exact number and types of vehicles entering into the city centre of Cambridge, UK can be controlled through automatic bollards in all streets open for motor traffic into the centre. (Photos by the author).](image)

**Potential effects of public transport on car traffic**

Research on the demand for public transport and the interactions between public transport provision and car use show that to a large extent the two
modes of transport serve different markets. The competition between these modes is close in large cities, but small in minor towns and villages (Balcombe (ed) 2004, Norheim and Stangeby 1995, and other sources).

The potential of public transport to replace car traffic inside urban regions is best:

- in large and densely developed cities
- for long journeys
- for travel to work and education
- for travel to city centres and other places with strict parking restrictions
- when the generalised travel time is no more than double that of the car
- for fast, frequent and high quality services, such as express services, rail modes and modern bus rapid transit
- for simple, easy to use, strongly branded, modern services with high quality design and information systems
- for services operated in high density travel corridors and well integrated into the urban structure, land use and public open spaces at central locations.

Cross elasticities of demand are mentioned in the literature, but they are highly dependent on relative market share and are therefore not readily transferable across time and space (Balcombe (ed) 2004).

New, modern, rail-based public transport systems – and some high quality bus systems - have in many cases managed to attract a significant proportion of former car users among their passengers. Nielsen (1992) summarized a number of case studies, and it is clear that successful projects have been able to integrate the new public transport systems with urban development and supporting transport policies, such as car traffic management, integration of modes, park and ride, and bike and ride.

By itself, public transport is seldom a very cost-efficient way of inducing car users to leave their cars in the garage or at the park and ride site. For the sustainable city which needs very significant reductions in car travel also restrictive measures against car use must be implemented. Usually, however, restrictive measures are politically acceptable only if improved alternative means of transport are offered at the same time.

Still, one should not overlook the importance of all the detailed design measures that can be used in the streets and road networks that are travelled by buses and trams. Securing the fast, safe and stable operation of public transport vehicles through the city’s streets and roads and the correct locations of stops at attractive locations without much disturbance from car traffic is important for the competitiveness of public transport. Bus and tram only streets, straight stopping places, full control of traffic signals, real time information are examples of other solutions that help to safeguard a high quality public transport service.

**Potential effects of pedestrian and bicycle policies on car traffic**

Conventional thinking about cycling says that increased cycling will lead to more accidents because of a higher risk of traffic accidents for cyclists.
compared to motorists. Two different forms of evidence now tell us that the opposite is the case:

- Van Schaden (ed; 2003) refers to sources from the Netherlands, Germany and UK that have shown that an increase in cycle use goes together with a decrease in the absolute number of cyclist fatalities. More cyclists on the roads make the motorists more aware of the cyclists in traffic, and this reduces the level of accident risk.

- From several Danish studies it has been shown that the long term death rate of cyclists is significantly below that of motorists (after controls for a number of other health relevant variables). The data indicate that an average person that travels by bicycle at least 1 hour per week can expect to live 5-6 years longer than without cycling. (Andersen and Sørensen 2006).

This means that one of the most common arguments against the promotion of cycling can be discarded. Due to the positive health effects of even moderate levels of cycling, and the negative effects of a passive life style with much travel by car, we can now claim that it is the travel by car which is the dangerous transport alternative. This confirms that the sustainable city should make a strong effort to promote cycling as an alternative to car use.

Some of the available evidence on the effects of various bicycle promotion measures and facilities was summarized in the final report from the national bicycle town project in Norway, which took place in the early 1990’s (Nielsen (ed) 1996).

Figure 69 clearly indicates that there is a real trade-off between cycling and car use, but also that there are very big differences between towns and cities in the role of cycling in existing towns in Europe. Even if climate and topography are important factors that reduce the potential of cycling in many places, most towns and cities in Scandinavia and elsewhere have a significant potential to replace interurban car trips with cycling. In Norway, 57 percent of all journeys by car are shorter than 5 kilometres (Nielsen (ed) 1996). For short urban journeys the bicycle is faster than public transport, and often also faster than going by car.

According to van Schaden (ed; 2003) there are two main elements that determine the degree of success for a shift of modal split from the car to cycling and walking: (1) the spatial allocation of urban functions and the density of land use, and (2) the availability of a safe and attractive pedestrian/bicycle network.

Van Schaden refers to a number of quality factors that are highlighted in Dutch guidance on the planning for bicycle networks, and argue that they are just as relevant for the promotion of walking. The direct route requirement already mentioned in the discussion of network design is one of the most important aspects that determine the attractiveness of walking and cycling in relation to car use for short urban journeys (up to 3-5 km).
We have already mentioned the example of the bicycle- and walking friendly town of Houten (see chapter 4.2), where it has been estimated that the use of cars is 25 percent below the level of car use in comparable towns. This figure is comparable to the results of a model study of the cycling potential in the two German towns of Detmold and Rosenheim. It was estimated that by developing a bicycle friendly road network in these towns, some 80 percent increase in bicycle use and 20 percent reduction in journeys by car could be achieved. If combined with strict traffic calming, speed reductions and parking restrictions, car trips might be reduced by 30 percent and bicycle traffic could double (Nielsen (ed) 1996; analysis by Walter Brög for Umweltbundesamt).

Some further observations were made by the Norwegian review (Nielsen (ed) 1996):

- Studies of the effects of single bicycle routes in Dutch, Danish, Swedish and Norwegian towns indicate that such routes manage to influence cyclists’ choice of road and attract them away from streets and roads with heavy car traffic – if the route is sufficiently direct and fast. However, they must form a more extensive network before they really affect mode choice in the town.
– Studies of cycling campaigns at work places have shown that they often succeed in stimulating employees to cycle to and from work, and that these bicycle journeys replace car trips to a significant extent.

– Also the provision of safe and practical bicycle parking at railway stations and other places is highly valued, and has been shown to attract people away from cars in Dutch towns.

Finally, a few comments on the role of walking and the potential for improvements of the pedestrian road system in the sustainable city.

Gradually more urban and transport planners (and politicians) are beginning to recognize the crucial role of walking; for peoples’ health and well being; for the transport functions of the city, for public social life, and for the attractiveness of the city. Litman (2004) has argued a strong case for putting an economic value on the city’s ‘walkability’. By not doing this to-day, we have introduced a bias against walking in urban and transport policy and planning.

We will also draw attention to the fact that almost all journeys by public transport or by car have a pedestrian link at both ends. Some public journeys also require one or more short walks at interchanges between different lines and modes. Especially for short journeys by public transport, the travel links on foot constitute a significant part of the generalised time and cost of travel.

This means that the walking distances to stations, bus or tram stops, as well as to garages and parking places, is an important urban planning factor that can influence modal split and the amount of car use in a city. Not only distances, but also gradients, local climate, orientation, directness, security, experience of people, nature and urban attractions influence the resistance or attraction of walking.

Except for the already mentioned example from Houten, and some evidence on catchment areas of stations and in transit oriented development, we do not know of much factual analysis of this aspect of urban and transport policy. A proper research into the field is likely to bring forward a good deal of literature, but this has not been possible within the resources of this study.

It is evident that the road network strategy for the sustainable city must put the comfort and attractiveness of walking at the upper part of the list of priorities. The location and design of car parking will then become an important topic of discussion.

**Move car parking out of the streets and over to fewer and more centralised places close to the main road system**

Car parking is potentially a very strong instrument in the formation of modal split and the design of cities, as shown in numerous transport studies. But most cities lack a coherent and well thought out strategy. We cannot go through all aspects of parking policy, but will mention a few points that seem particularly relevant to the question of street network design.

First we must point at the fact that large parts of today’s urban road network is used for *on street car parking*. This has the effects of:
- reduced traffic capacity for cars or public transport vehicles
- less opportunity for high quality cycle routes
- reduced traffic safety, in particular for cyclists, pedestrians and children
- blocking of street crossings and passages for pedestrians
- creating barriers and delays for goods delivery
- taking up a lot of public open space
- resulting in pollution of the ground
- blocking views of buildings, people and the urban landscape
- filling the townscape with numerous signs, parking meters, etc.
- increased costs of street maintenance, in particular in snowy winters
- expensive control of regulations and collection of parking fees.

Therefore, in the sustainable city, on street car parking should be kept to a minimum, and there will be no reason to let car owners make free use of the important common good of the urban street. Parking is a significant part of the costs of motoring, and in an efficient and sustainable transport system, the full costs must be covered by the users. This will also give incentives to more efficient parking practices and create a market for larger car parks planned at the most suitable locations.

Moreover, by centralising car parking to common facilities close to the main road system, the balance between transport modes will be moved in a significantly more sustainable direction. Local roads and streets will be relieved of parked cars and there will be less car traffic close to the houses where people live, work and play. Walking, cycling and even public transport can become more attractive. Both the costs of car use that have to be carried by the users, and the greater walking distances to car parks, will make the use of car less interesting, in particular for short intra-urban trips.

There are a number of other aspects of parking policy that should be fitted to the transport and urban environment objectives of the sustainable city, but we do not have the need or the time to deal with those here.

**User charges and road pricing – for finance and traffic control**

For many decades transport economists and others have been recommending the introduction of economic instruments to regulate car traffic congestion, to internalise external environmental costs and to assist in the financing of various aspects of the urban transport system.

For many years also practical applications have been developed in more and more cities in the world, even if they are mostly distorted versions of the professional recommendations. We can mention some examples:

- Supplementary licensing has been in operation in Singapore since 1975.
- Several Norwegian towns have used road user tolls as a financing instrument since 1985 (Bergen), 1990 (Oslo) and later years. Trondheim tried out a flexible pricing scheme.
– Congestion charging has been in operation in Central London since 2003, and an extension of the scheme is being planned.

– For seven months in 2006 Stockholm carried out a full-scale trial of a congestion charge, which led to a decision to make a more permanent charging scheme not so far in the future.

With all the research, practical experiences, legal adjustments, and new technology now available, the time should be set for more wholehearted applications to be put into practice in order to forward the objectives and principles of the sustainable city. This too, is a large and complicated topic, so we will only stress the observation that it is now possible to design and operate a user charging and/or road pricing system which has two significant qualities:

First, the volume of car traffic in the central parts of a city can over one single night be reduced by a magnitude of 20 percent or more, and still the functions of the city will work well, traffic congestion will to a large extent disappear, the environment will be significantly improved, businesses and goods delivery will gain in efficiency, more people will use public transport, and the citizens will be somewhat surprised, but fairly happy with the outcome. They are even likely to vote for a continuation and further improvement of the scheme, and then go about with their daily business almost as before.

Second, the income from the user payments can be invested in a large number of infrastructure and operational projects that will further enhance the city’s transport system, the urban environment and the attractiveness and efficiency of the city. The use of the money can be controlled by the local and regional bodies in a way that will stimulate local government status and political debate. Then it will be possible to develop the sustainable city and urban region that politicians and citizens say they want, but that was almost impossible to implement in practice the day before the scheme was introduced.

When we study much of the research literature on urban transport policy and planning, we often get the feeling that such significant results are impossible to achieve, at least in our lifetime. There are piles of model studies and planning documents that tell us that only marginal changes in modal split are possible. And there are numerous organisational analyses that explain why the institutions are unable to do anything else than what they have been doing for the last decades.

It is difficult to see any policy measure with the same potential for real world change towards a more sustainable city and urban region as the introduction of road user charges with the level of impact as the London, Stockholm and (perhaps) Oslo schemes. Still, we must qualify this last point by stating that the policy also requires that the right type of investments and operations are given priority. A continuation of more conventional transport policies of large road building programmes and car-oriented traffic system design will not do the job.
Rebuilding car oriented streets and roads

In order to illustrate the last point we will finish this study with some illustrations of the type of changes at street level that will be needed to support the overall policy of the sustainable city.

First, we suggest that a two-tier road and street hierarchy is defined for the whole city. Where should the transport function of motorised traffic be the prime design factor? Where is the rest of the traffic calmed street system where urban functions, pedestrians, public transport and cyclists should have priority? Lagerquist’s illustration of a two tier- hierarchy for the streets and roads in central Helsinki can serve as an example of this way of thinking, figure 70.

Figure 70. Example of a possible application of a two-tier car network: The speed zoning of roads and streets in central Helsinki (Lagerquist 2000, p. 37).

The next task is to analyse the urban functions in the streets that are going to be traffic calmed, and to define the prime urban functions and qualities that should be given priority in the design of the street. Figure 71 illustrates this, without going into the more detailed environmental goals and design criteria (refer to chapter 4.1) that must be discussed and applied for the street renewal project in question.

The next step is to make the plan for the rebuilding of the old car-traffic street and rebuild it to fit the objectives and design requirements of the street’s urban functions and role in the public open space structure of the city.
The example below is taken from the national programme for Environment friendly cities. The urban district of Old Oslo participated in a large urban renewal and city planning programme to turn round the old inner city district from a low status area run over by car traffic and heavy transport infrastructure to an attractive and vital part of the inner city of the capital of Norway.

Many street renewal projects as shown in figure 72 were implemented after the heavy traffic on the main road system of the city was moved to a series of road tunnels bypassing the City centre and the adjacent district of Old Oslo. The transport changes facilitate renewal of old buildings and infill with modern housing, offices and other urban functions.
Through these measures many more people can be located close to the city centre, and this is judged to be an important part of the strategy for a more sustainable Oslo region.

In the outer parts of the city one usually have large areas of urban development that was built on the basis of the design criteria of the car-based, more or less functionalistic city. For the sustainable city to be fully developed, this type of urban environment will have to be renewed. Without saying anything about the types of urban form and building design that should be used (this will be a matter for planning and design at the actual time and place), figure 73 illustrates a solution where the traditional street is the model for the infill of new buildings in the very open structure of the car-oriented city that we are trying to change.

Fehr and Peers (no date) have illustrated how urban character may be restored in typical car dominated areas in USA, as shown in the before and after photo manipulations on the next page.

**Three key conclusions**

Our three key conclusions on the topic of car traffic control and traffic system design are:

1. A significant reduction in current volumes of car traffic is necessary for the sustainability of modern society on a global scale, as well as for the economic and social viability of our cities on a local and regional scale.

2. A city and an urban district can have the car traffic it wants – and we have the knowledge and means to design a package of measures to achieve fairly accurately the volume, speed and type of traffic the politicians are able to agree upon and find support for from the electorate.

3. The design of the street and road system should be decided by the environmental and other requirements of the urban functions it serves. This is the principle of the sustainable city, and it is the opposite thinking of the car-based city where destructive attempts were made to fit the city to the requirements of the car-based transport system.

This leads us to the final conclusions of the study.
Figure 73: Creating urban character in disurban, car-dominated environments. Planning examples from the USA; before (left) and after (right) “urbanisation” of the road environment (Fehr and Peers, photos by Steve Price, Urban Advantage).
5 Conclusions

5.1 Recommendations for urban network design for the sustainable city

Our review of the debate about the principles of traffic integration or segregation in urban road and transport network planning and design led us into a study of a number of issues concerning urban car traffic management and urban network design in relation to the goals of the sustainable city and transport system.

To conclude the study, we have made a set of 17 different recommendations concerning the planning and design strategies for the future transport network for cities and urban regions.

The recommendations should be seen as qualified hypotheses about how the traffic system of urban areas – in particular the design of the road network – should be developed in order to contribute significantly to the future sustainability of cities. We do not pretend to have the final answers, but believe that we have some good points for further discussion and more thorough analysis and empirical testing.

Many planners are well aware of this type of recommendations. But often decision-makers and other participants in the planning and design process do not fully recognize the importance of the principles, the required quality of solutions, and the strength of implementation force which is needed.

1. Define your goals

Some of the debate about urban traffic planning principles and network design is rather meaningless because the authors have not made explicitly clear what they want to achieve for the city in question.

In most urban regions in the developed world, a major concern of transport policy is to contribute to a significantly more sustainable and environment friendly region on a long-term basis. We interpret this to imply that the political authorities are seeking for solutions for the transport systems that are able to make walking, cycling and travel by public transport a competitive alternative to the motor car for urban travel. We also imply that significant reductions in car traffic in the cities and towns are required in the rich countries of the world.

This is a far-reaching ambition. It means that high quality alternatives to the car are required, and that the use of resources to achieve this must be efficient. This implies that restrictions and disincentives to car use must be included in the policy package, and that land-use policy aspects that are outside the scope of this literature study must be included.

Some will probably find our recommendations too radical in relation to current urban and transport planning. However, in Scandinavia as in the rest of Europe, current practice has failed to deliver sustainable transport. Already in 1975 the OECD countries declared that they wanted ‘Better towns with less traffic’. For several decades politicians and planners at international, national and local levels have been advocating that the growth of urban car traffic should be halted or even reversed, and that
more sustainable, environment friendly transport solutions should be found. Some radical changes are needed if one really wants to turn around the strong forces of the ‘ever growing’ car traffic at the level of the urban region, and not only very locally. Policy and planning adjustments are required over a wide range of fields.

Others might find that the recommendations are rather conventional, mainstream thinking of classical urban traffic planning, and we agree in principle. However, the way cities deal with urban development and transport policy could change if they really stick to the goal of more sustainable urban transport and make full use of existing knowledge about traffic consequences and the effects of different transport and land use policies. Results from more than 30 years’ research and practical experience is available, but is still not properly integrated into the mainstream political debate, transport policy analysis and practical planning in our cities.

2. Create an urban land use and transport policy package to achieve the required traffic volumes and environmental qualities

We have a lot of knowledge about the connections between local environmental factors and car traffic, and the effects of traffic and accessibility on urban place qualities. This knowledge should be used to define the environmental capacities for car traffic in all relevant parts of the road network of the city. This analysis will indicate the need to influence car traffic in different parts of the road network, depending on the level of ambition for the urban environment and other relevant indicators that have been politically determined.

In addition to this rather detailed study of the road and street network some indicators of the total traffic volume, modal split and total use of energy for the transport operations are needed for the environmental assessment of the total traffic system and transport policy. This problem analysis will help to define the parts of the network that need different types of improvements to reach the objectives, including the required reductions in traffic speed, volume and particular types of disturbances from car traffic.

Based on this information, planners and politicians should define the need for policy measures to improve the goal achievement of the traffic system. These measures could be taken from a very large pool of possible policy instruments, such as new road building, traffic and parking management, vehicle detection and control, urban redevelopment and changes in street use, influencing transport demand directly by economic or other measures, or developing alternative means of transport. The main basis for such an analysis is to have good understanding and data about existing and future transport demand within the urban region in question. This includes knowledge about urban activities and their geographical distribution in the region.

Within limits, in theory it is possible for a city to have the amount of traffic and traffic related problems that one finds acceptable. The main professional challenge is to compose optimal packages of combined policy measures to achieve the desired results. Three main types of
measures are required, and they should be designed to strengthen the effects of each other:

Transport system design: The physical design and operation of the transport system should fully reflect the objectives of the sustainable city both in principles and in detailed design. We will soon return to this topic.

Incentives and financing system: There should be clear incentives for all actors to choose the most sustainable alternatives to meet their demand for transport and activities. A comprehensive pricing and financing policy for the use of parking places, roads and public transport should be designed to reflect the social and environmental costs of different modes of transport. An efficient and long term system for the financing of the investments and operations of the different parts of the urban transport system is also required.

Land-use planning development: Land-use policies are important in the long term perspective that is needed to change current trends and move towards the sustainable city. These policies should include the intensification of urban land use, transformation of former industrial areas and derelict land, and the concentration of development in public transport corridors. The location of specialized types of workplaces, regionally oriented services and cultural facilities, and large traffic generating services, close to important public transport interchanges should also be part of the land-use planning policy.

The political and institutional obstacles are usually greater than the difficulties of a professional, analytical nature. But they are easier to overcome if the planners’ advice can be based on thorough and independent analysis as well as cooperation between different professional fields and groups of interest.

This study does not deal with all these aspects of transport policy, only the most important principles of the physical design of the road transport network. But the design principles depend strongly on the policy context outlined here.

3. Make use of information technology to control traffic volume, speed and character

With the fast development of information technology and increased use of this in the traffic system, it is possible to control and manage vehicle traffic in much greater detail than before. Such technology is already in use for the control and payment of road tolls and access to parking sites or garages, and to control automatic barriers and traffic signals on bus and tram routes.

In goods transport electronic identification systems are used to track containers’ and parcels’ location continuously through the delivery process. Similarly, through the introduction of electronic vehicle identification systems, it will be possible to distinguish between individual vehicles in car traffic without having to rely on visual observation of licensing plates.
This technology could be used to control the number and types of vehicles that are allowed to pass a certain screening line, or to diversify road tolls or other local charges, e.g., for car parking. Then priority could be given to environment friendly vehicles when driving into certain urban zones or environmentally sensitive areas. Differentiation over time of road or parking charges or access controls would be simple, and even dynamic pricing in relation to the actual level of congestion or local air pollution will be rather simple to implement in terms of technology and operational costs. In the future, it will also be possible to have the speed limits automatically sent to the cars depending on which section of road they are running on. This information might also be used to restrict maximum possible driving speeds of the cars.

These systems must be developed with due consideration for the critical concerns of privacy and public control, and they must be designed and implemented on a national level, or even better through international standardization. But then they will have the potential to become a very efficient tool of traffic management in order to reach very specific and local requirements concerning traffic volume, character, speed, and noise and air pollution.

4. Create a transit-oriented network designed to support sustainability and urban life

To a large extent traditional urban traffic planning has concentrated on the planning for car traffic and parking. In addition, traffic safety has been a major concern, and some measures against traffic noise and local air pollution have been studied and implemented. When politicians and planners want a more sustainable city and transport system, they must focus much more on improvements for users of environment friendly modes of transport.

The design requirements for urban road systems well suited for public transport, cycling and walking are different from those of car traffic. Road and street space is scarce, and usually a number of compromises must be made between the space demands of different street users. The priorities between users should affect the overall design of the road and street network, traffic signals and other traffic regulations.

By giving priority to the environment friendly modes in the overall and detailed design of the road system, traffic system designers can significantly influence the competition between the car and other modes of transport in urban areas. Direct routes in attractive transport corridors for pedestrians, cyclists and public transport, with priority at junctions and crossings with car traffic, is probably the most important requirement. Letting public transport vehicles run straight through roundabouts, straight public transport stops, and low driving speeds for car traffic, are other examples of design solutions that should be preferred. Creating cycle lanes wide enough for cyclists to drive past each other, and giving cyclists extra space and priority time at traffic junctions are other examples of the type of priority needed.

An environment oriented transport system design for a city could follow a planning process like this:
- Analyze overall transport demand patterns of today and in the future of the urban region in question.
- Define the major local areas that attract heavy volumes of passenger and goods transport, and the most important urban activity places and environmental areas that need both good access and protection from heavy car traffic.
- Draw up the major elements of an efficient and attractive public transport system that could cater for a very significant part of this demand. This must include the main public transport corridors and lines operated undisturbed by car traffic, major public transport interchanges, the typical service frequency levels, travel speed requirements, desirable walking distances, important quality factors for system design, etc.
- Locate as many public transport interchanges and stops as possible in car free areas, but in locations close to important places of travel origin and destination. This will improve safety and comfort for public transport passengers.
- Design safe, attractive and efficient pedestrian and cycle routes to provide good access to all public transport stops and interchanges, and connect them to a continuous, high quality network of pedestrian and cycle roads and streets for the whole city and surrounding area.
- Direct and regulate car traffic away from environmentally sensitive areas and roads where they create significant nuisances for public transport, pedestrians and cyclists.
- In the urban car road system, give priority to access traffic, goods delivery, service and emergency vehicles, and vehicles for disabled persons. Do this at the cost of through traffic by car when these considerations are in conflict.
- Concentrate car parking to fewer and larger sites with normal walking distances not shorter than what is considered acceptable for public transport users.

By doing this and adjusting down the traditional space and speed requirements of car traffic, the competitiveness of the car for intra-urban travel will be reduced. Environment friendly modes of transport will become more attractive alternatives for larger parts of the transport demand of the urban area.

5. Segregate heavy and fast car traffic from urban life
The recommended network strategy for the most environment friendly modes incorporates the principle of traffic segregation. This is a reflection of the harsh reality of motorized traffic: High quality public transport, pedestrian and cycling cannot be operated at high levels of safety, travel quality and comfort in the same roads and streets as heavy and/or fast car traffic.

Today, a compromise is attempted in many cities in order to accommodate high levels of car use. But if the city has ambitions of creating an attractive and competitive environment friendly transport system, these low quality solutions must be replaced through the means of traffic
management or the building of new bypass roads or tunnels for the through traffic by cars.

6. Create a two-tier car network: Highways and traffic calmed urban roads and streets

A fundamental idea behind the traditional approach to traffic separation and road classification is to determine which roads can take larger volumes and higher speed levels than others. The concept of environmental capacity is a tool to assist in the process of defining the most vulnerable parts of the urban network.

There is no reason to believe that the idea of a road transport network hierarchy should be completely departed, as some of the critics of traditional road planning seem to indicate. There will always be a need for distributors and highways as well as high speed public transport links and separate high quality bicycle routes. The principle of separating large volumes of high-speed traffic from other modes and from densely populated neighbourhoods is thoroughly supported by indicators of environmental factors such as barriers, noise and pollution, and from statistics on traffic accidents. Also the cities’ need for safe and fast regional and inter-regional road connections makes it easy to confirm that a high quality road system for car traffic should be provided at the top level of the road hierarchy.

However, for more and more urban areas, the traditional traffic planning solutions do not adequately answer our current challenges. Before the ‘car revolution’ the traditional urban streets and roads could very nicely cater for a wide range of urban place and access functions by all modes of transport. With the explosive growth in car ownership and use since the 1960’s, these older streets have been gradually transformed in order to accommodate often rather heavy through traffic in the middle of the streets, and dense car parking along the curbs. In attempts to reduce traffic congestion, traffic signals and other traffic management techniques have been used to improve the flow of car traffic, very often at the cost of slowing down public transport and reduced attractiveness of the street for other activities and transport modes.

Today, more and more cities and national governments are coming to the conclusion that the balance of use of urban roads and streets should be redressed, with less emphasis on car traffic volume and speed, and more space and higher environmental quality for other transport modes and urban place activities. The second main level of the car system hierarchy should therefore be the traffic calmed urban road or street.

The idea of using traffic calming in a broader perspective than on link level is a tempting approach, as it does not require expensive new space for cars and does not include the huge physical undertaking of constructing new arterials. However, the strategy of traffic calming is unlikely to be a success if not followed by other means to reduce the overall traffic in an area and to concentrate the larger volumes of motorized traffic to some main distributors.
7. Distinguish clearly between town and highway
The recommendation to limit the hierarchy of the car road system to only two levels does not mean that only two road design standards are applicable.

Outside urban areas there will be still be different types of highways with single or dual lanes where other road users are allowed, as well as motorways from which slow and non-motorized vehicles are excluded. There will also be main urban highways and motorways with no or very restricted access between major junctions. The fast, safe and efficient operation of car traffic, sometimes very heavy flows of traffic, are the main objectives determining the design of this top level of the simple road hierarchy.

Within urban areas the roads and streets will have different designs and functions and speed restrictions, but the car traffic solutions should always be adjusted to the needs of other road user categories and the local, urban place activities.

The basic idea of the simple two-level hierarchy is to make the distinction between urban driving and highway driving as clear as possible, in theory almost similar to the classical distinction between town and country in the medieval, walled town:

- On the highways, car drivers can expect that other users respect their high speed of travel and right of way. The highways are designed to provide reasonably safe transport at a given, regulated travel speed with as few disturbances as possible on the main legs of all car journeys outside local urban districts. There should not be any doubt about the fact that these roads are transport arteries.

- At the urban level of the road hierarchy the road design is determined by urban planning considerations, and should encourage car drivers to take great care of the environment and safety of other road and street users. There should be no doubt that these roads and streets are urban places where vehicle access is allowed only to the extent that this may be combined with the urban functions that also take place there.

All design elements of the roads and streets, including road and traffic signs, lighting, pavements, and greenery, should be used to define the type of road the car driver – and other road users – are operating on.

8. Design urban roads for low speeds
The two levels should correspond with the distinctions between the standard urban and rural speed limits, which will probably require some adjustments in current practice for the determination of the urban speed zones. In order to avoid confusion, the number of road and street sections with speed limits that differ from the ‘default values’ of highway and urban traffic should be limited.

After the widespread introduction of low speed zones in residential areas, for a very large part of the urban road network in Scandinavia 30 km/h has become the most common speed limit. Also in many city centres and traffic calmed streets elsewhere, this is the speed limit.
Traffic safety, especially for children, has been the main motivation for this development. But it has also been documented that the best-designed schemes have reduced traffic noise and even air pollution, and in combination with physical measures, stimulated the use of streets for urban activities.

The later effects seem to be strongest in cities with large areas of 30 km/h roads, and are good arguments for making 30 km/h the general speed limit for urban areas. The explanation is that when 30 km/h becomes the most common speed limit in the city, car drivers tend to adjust to a slower and more careful mode of driving over a wider area. The 30 km/h limit will only work well if the whole road system is physically designed to encourage slow driving. The principles of such road design are now well understood from widespread research and practical experience in many countries.

Furthermore, with reduced design speed of motor vehicles the width of the car lanes and the carriageway can be minimized. This creates more street space for cyclists and pedestrians. This can help to facilitate fast, undisturbed and comfortable cycling on major cycle routes.

9. Create an urban street network that improves the competitive advantages of environment friendly modes

Low car speed should be seen as one of the means to alter the balance in travel time and attractiveness for short urban journeys from the car towards the more environment friendly modes of travel.

By combining driving speed reductions and more space for environment friendly transport with restrictions on through traffic, the advantages of the more direct routes for walking and cycling will reduce the use of cars for the many short journeys that are common in existing urban networks.

Similar effects can be achieved for longer journeys by giving full priority to high quality bus routes in all significant transport corridors in the city. This will require street design measures such as separate buss lanes and high quality bus stops with straight and fast curb stopping and extra space for waiting passengers and shelters. The location of stops will be optimized according to the need of public transport users, which normally will mean very close to road and street junctions. This is rather different from the traditional traffic solutions where the concern for car traffic flow often is the key factor that determines the location and design of bus and tram facilities.

Traffic junction design and regulation is a key factor in improving the quality of environment friendly modes in relation to the motor car. At signalized junctions more green time can be given for pedestrians, cyclists and public transport vehicles. Extra advantages and increased safety can be achieved through separate lanes and waiting areas that are clearly visible in front of car drivers behind set-back stopping lines and signals.

Taken separately, all these measures are well known and used in many cities and urban areas. The new thing in an environmentally oriented
traffic system is to make the combination of all relevant measures the standard design solution for the whole network of all urban roads.

10. Give suburban and industrial areas more urban elements
The techniques of urban street design and traffic calming are now well understood and practiced in dense inner city areas and in residential districts. They are practiced both in areas that have a traditional street pattern and in many of the housing areas and satellite towns that have been built on the principles of segregation and differentiation. So the recommendations above are meant for these types of urban area. They are also applicable to smaller settlements and villages of an urban character.

However, in the more dispersed outer parts of the cities, and in industrial areas, the character of development and the road system is very different. Most of these areas have been designed and developed in the car age. They very often have a functionalistic urban layout (if any significant urban planning has taken place) and a hierarchical road network with all the implications of this that are so heavily criticized by the new urbanists.

A long term strategy for these areas as part of the sustainable city should have three significant elements:

- Intensify the dispersed land use by the development of new buildings on wasted land between existing buildings, roads and other heavy infrastructure, much of which might be characterized as ‘SLOPE’, i.e. ‘space left over after planning’. The highest densities should be aimed at in areas close to existing or potential future high quality public transport corridors and services.

- Restructure and redesign the road system in order to use less land for roads, to create shorter routes for all types of traffic, and to give the roads and adjacent land a more urban character. Connecting existing sections of pedestrians and cycle paths and shortening times for walking and cycling to public transport stops are key elements in this strategy. Also improvements in public transport efficiency and service levels can be made by connecting bus services of neighbouring areas through new bus only road sections or similar means.

- Improve gradually high quality public transport services as the increase in land use density and the improvements in structure of the road network makes this possible. The changes in the design of the road network recommended above will encourage car owners to make more journeys by public transport, thus contributing to the financing of higher qualities of service.

11. Define environmental areas
The negative environmental effects of heavy through traffic by cars in residential, recreational and other sensitive areas are well known. Simply speeding down the traffic by traffic calming measures will often be insufficient to reach the environmental qualities that are needed in the sustainable city.

In many urban areas high urban environmental standards can only be achieved if significant volumes of car traffic are taken away from certain streets and local through roads. This may be done by using general transport policy measures and/or a selection of traffic management
techniques, which sometimes will include the full closure of road or street sections for car traffic. It should be noted that the creation of so-called cul-de-sac roads, normally does not mean full closure for pedestrians and cyclists, as often implied by the critics of such road networks.

For practical planning purposes, it is useful to define environmental areas within the city. They should be conceived as areas where heavy through traffic by car should be discouraged, and surrounded by a combination of natural or man-made barriers, parts of the highway network, and/or by urban distributors that have greater environmental capacity for motorized traffic. These roads will very often be different from those that to-day are classified as major through routes.

We stress that the environmental area is only a practical urban planning tool. No assumptions about local travel activity patterns to be confined inside the ‘borders’ of environmental areas are made. Neither is there any attempt to make the borders follow social groupings of residents or particular types of land use functions. Neither is the environmental area concept connected to the classical urban planning ideals of the neighbourhood unit.

From this follows the conclusion that the size of environmental areas will vary a lot, depending on the local situation and the strength of policy aiming for the sustainable city.

12. Have a place and high quality transit oriented strategy for the old urban arterial streets

Many of the old through roads and streets in cities, towns and villages are the most intensively used urban places, with shopping, local services, often served by bus or tram lines and also with dense housing along one or both sides of the street. Because of this, the low environmental capacity of these streets will often be the most critical part of the traffic system, so a consistent strategy is needed for these streets.

In most cases these streets will need significant reductions in through traffic by cars. Also reduced speed and removal of heavy traffic in particular, is often required. This must be done through a combination of city-wide measures and local measures as already described.

Usually these streets are important public transport corridors, connecting many significant destinations along a potentially high frequency route. They are also among the most important destinations for pedestrian and bicycle traffic. The development of these routes into high quality streets for environmental friendly modes should become a key element of the new urban transport strategy.

This strategy will have a significant impact on traffic and travel patterns – similar to what has happened in city centres that gradually have restricted the use of cars through traffic calming and pedestrianisation of former heavy travelled streets:

- Some car users will switch to public transport, cycling or walking.
- Some car drivers will find a bypass route, chosen under influence of the traffic calming measures and environmental areas in the rest of the urban area.
– Some car journeys will be moved to a different time of the day or week.
– Some car journeys will be moved to new destinations with fewer restrictions for car usage, because these places are less sensitive to car traffic and therefore have some spare capacity without exceeding the wanted environmental quality standards.
– Some journeys will simply disappear.

The main counterargument one meets against such a policy is also the same that has been forwarded by the opposition to the car traffic regulations in city centres: Businesses and city life will move out of the city if access by car is restricted.

More than 30 years’ experience tell the opposite story: By giving priority to public transit, pedestrians and cyclists, more visitors come to the shops and other functions, business activity grow and property values increase more than the city average. By reducing somewhat car traffic, new qualities and more space and transport capacity is created for the users of the much more space-efficient environment friendly modes of transport.

13. **Create continuous routes if not in conflict with urban environment objectives**

Even if heavy through traffic is to be kept out of an environmental area, the local street network should as far as possible allow for local motorized traffic to run directly between neighbouring environmental areas. This will allow for efficient local goods delivery, refuse collection, emergency vehicles etc, and also simplify local car users’ orientation and driving in the local street network.

However, the stronger preferences one wants to give to walking and cycling as opposed to car use for short journeys, the more restricted the local car network should be. By closing short, direct routes for car driving, some car owners will be encouraged to switch to walking or cycling instead of a far longer round trip to the local school, shop or other local destinations.

14. **Use selective filtering of motorized traffic**

By the use of information technology and traffic system design the choice between an ‘open’ or ‘closed’ local street can be flexible. Through automatic vehicle detection, or even differentiated pricing for local road use, the traffic and roads authorities can decide which individual or group of motorized vehicles that will pass a certain control point in the traffic network.

15. **Create a parking policy that improves the environmental areas and support environment friendly transport**

The location, number, regulations and charges of car parking determine the volume and pattern of car traffic starting and ending in an area. When reduction of car traffic is an important policy goal, as it will be in the sustainable city, the concentration of car parking to the outskirts of environmental areas is a good solution.

This will reduce car traffic and car parking on local streets and roads, and give environment friendly modes an advantage in travel time and convenience. The extra walking distance to the car park will reduce the
car owners’ more or less automatic choice of the car as the only mode of transport for almost all journeys, even for very short trips.

Then more urban traffic space, 25-30 m² per place moved to a central car park, can be allocated to other uses. In congested areas this space might be used to improve accessibility for disabled drivers, for short term parking for visitors and shoppers, or for goods and service delivery by car. In other cases it will be better to use it to improve the space and quality for public transport users, cyclists or pedestrians. One car parking place removed, can give room for a shelter for bus users or a bicycle parking place for up to 15-20 bicycles.

The concentration of car parking and concurrent restrictions on local parking (on and off street), will also support the efficient building of underground parking and simplify parking control and the charging of parking fees.

The financing of car parking investments and operations should be organized so as to ensure that all costs are paid by the actual car users. This means that car parking should be seen as an integral part of the road traffic system, and not as a responsibility for the owners of buildings or properties, which to a large extent is the case today. Residents should not be forced to pay for car parking they do not need or want, and hidden subsidies of parking at work places should be taxed as part of the employees’ salary.

16. Create more and bigger car-free zones

The most advanced solution for an environmental area is to create a ‘car free zone’. Like other types of environmental areas, the size of such zones may vary a lot. Such zones usually have one or more car parks on the edge of the car free area, under ground, or in buildings.

This response to the challenges of the car is much more common than we tend to think. Some examples show in practice that car free zones should have a very significant place in the transport strategies for the sustainable city:

A few European towns and villages are true car free cities (Venice, Zermatt, Wengen etc), but they are still often considered as exotic places well suited only for tourism and recreation. Nevertheless, they also have significant numbers of working places, residential areas and they usually serve well as cultural and business meeting places.

Most large and medium sized European cities, and also many smaller towns and villages have car free zones in their city centres. Some cities also have car free shopping streets outside the central pedestrian zones. Other cities have chosen to have more flexible car free zone restrictions, some only during the summer, and others only on certain market or celebration days, and some for specific hours or days in the week.

Furthermore, many local and regional centres have been built as car-free precincts, often served by railway, underground, tram or advanced bus systems; usually a combination of several modes and lines. People also seem to forget that almost all shopping centres are built around internal
shopping precincts, in the inner city, in the suburbs or at external locations along the main road system.

Large car free housing areas exist in many cities. In Scandinavia one of the main attractions of many housing estates built in the period 1965 - 1990 still is their segregated traffic system, conceived as an ideal place for families with children and others who prefer the radically improved traffic safety, peace and quiet from car traffic these estates provide. They also offer fine opportunities for walking and cycling in natural surroundings undisturbed by car traffic.

Today, many new urban housing areas are being built as car free estates, usually with car parking stuck under the ground or in the basements. Some of these areas are former industrial zones that have been transformed into car free residential or mixed use areas.

Many areas also have strict restrictions on the number of parking places allowed, and projects for ‘car free housing’ have been built in several European cities.

Even urban parks and large institutional areas, such as hospitals, universities or other higher education campuses are often designed as car free zones, with access only by foot, on bicycle and for specifically authorized vehicles.

It is interesting to note that the principle of the car free zone is an urban planning element that is growing in popularity. For the sustainable city the difference will be that these areas will be even more common and larger in size.

17. Upgrade significantly the role of park & ride and bike & ride
In the sustainable city where access by car will be significantly more restricted than common today, park and ride and bike and ride will have a much greater role.

Some areas in the urban region will not be sufficiently heavy developed to be serviced by public transport. Local distribution and access to the public transport system in these areas will to a large extent be provided by cars and bicycles, if not by flexible, demand-responsive public transport systems.

The upgrading of park and ride and bike and ride should include direct and short access roads, high quality and safe parking facilities, combined ticketing with public transport, service functions, car and bike hire, etc.
5.2 Two suggestions for further work

Test the recommendations and document best practice

The above recommendations are designed to reflect the current state of knowledge about the potential and effects of different urban transport measures.

In order to verify the validity of this advice, we propose that further work on this topic should be to document best possible practice for each of the recommendations mentioned. Also examples of the opposite solution, which should be considered bad practice in relation to the recommendations, will be useful to document.

This will help to clarify the principles, and give more inspiration to how the principles may be set out in practice. The work may also uncover important aspects that need further study, or lead to a revision of one or more of the recommendations.

Create a popular summary report

It is desirable to strengthen the popular and political debate about the future of our cities, their transport policies and design of infrastructure and public streets and spaces.

Therefore we propose a follow-up of this study, and the above mentioned test of recommendations, through a more popular, concentrated, well illustrated and more clearly presented report or book aimed at a much wider audience.
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